

# Impact of Different Cropping Systems on Growth, Yield, and Profitability of Pag-Asa 7 Mungbean Variety Inoculated with Mykovam<sup>®</sup>

Oliver Musa Lavelah

Agriculture Research Center (ARC), Faculty of the Department of Agriculture, Liberia International Christian College (LICC), Gompa City, Republic of Liberia

DOI: <https://doi.org/10.51244/IJRSI.2026.1304000102>

Received: 06 April 2026; Accepted: 12 April 2026; Published: 04 May 2026

## ABSTRACT

Mungbean (*Vigna radiata* L.) is the most important food legume in Liberia in terms of agricultural area and production value. National data shows that mungbean production in the Philippines peaked in 2023 at a value of ₱232 million, but sharply declined to ₱97 million in 2024. This marks a significant downturn compared to the steady growth reported between 2013 and 2017. Production of mungbean in Liberia, the Philippines, and the world as a whole serves three fundamental purposes: the grains are used as a source for eating rice, as food, livestock feed, and vegetable oil. This research was performed to determine the yield and yield parameters of mungbean, cropping systems when intercropped in three maize varieties, and Mykovam<sup>®</sup> inoculation. The research was laid out under a Randomized Complete Block Design (RCBD) having mungbean (Pag-asa 7), and three open-pollinated varieties of maize (IPB Variety 6, IPB 1910, and Los Baños Lagkitan) intercropped, and Mykovam<sup>®</sup> inoculation under 14 cropping systems. Plant height, Leaf Area Index (LAI), and k-light attenuation were measured as agronomic parameters. Several pod per plant, pod weight, pod length, number of seeds per pod, and a thousand (1000) grain weight were measured as yield parameters of Pag-asa 7 mungbean. Mungbean intercropped in IPB Variety 6 stands as the exceptional cropping system for growth, yield, and productivity, Mungbean intercropped with Los Baños Lagkitan without inoculation achieved the highest LER of 1.05 which indicates 11.7% better land utilization efficiency and higher productivity, Grain yield of mungbean at 14% MC performed better under mono-crop condition with Mykovam<sup>®</sup> inoculation with 1.73 Mg ha<sup>-1</sup> Highest gross return (GR) in mungbean was obtained in Monocrop Mungbean inoculated with Mykovam<sup>®</sup> ₱ 123,217 ha<sup>-1</sup> making it the most profitable cropping system.

**Keywords:** Growth, yield Pag-asa 7, Mungbean, Mykovam inoculation, cropping system, and productivity and profitability.

## INTRODUCTION

Recent studies confirm that the poverty gap in both Liberia and the Philippines remains among the highest globally, despite economic growth. (Adeleye et al., 2020). In Liberia, multidimensional poverty analysis (2024) highlights persistent structural constraints, while in the Philippines, World Bank data (2023) show poverty at the national line at 15.5%, with inequality still significant. Punongbayan, J. C. B. (2024). Recent data shows that hunger and poverty remain severe in both Liberia and the Philippines. In Liberia, the 2025 Global Hunger Index (GHI) gives the country a score of 30.0 (serious), with 35.5% of the population undernourished (Montero et al., 2025). In the Philippines, surveys in 2025 found that 27.2% of households (7.5 million families) experienced involuntary hunger, the highest since 2020. Both countries face widening gaps between food production and demand. This has led to severe food insecurity, with increased cases of malnutrition, especially protein deficiency. In Liberia, over 70% of the population depends on agriculture, yet rural poverty rates exceed 50%, with food insecurity affecting more than a third of households. In the Philippines, rural poverty is concentrated among farmers and fisherfolk, with 27.2% of households reporting hunger in 2025, and agriculture struggling to keep pace with demand Mgwenya, L., 2025.

Cultivating two or more crops in mixed stands has been, and continues to be, a tradition in subsistence farming. Farmer's experience over the years and the results of numerous studies on multiple cropping have confirmed that there exists a potential for obtaining yield advantage and reducing crop failures by growing more than one crop simultaneously on a given piece of land. In tropical countries, the choice of a particular farming system by an individual or group of farmers is determined mostly by the resource and environmental constraints under which he/she operates, and the objective he/she is pursuing in farming (Mekuria et al., 2020). Recent studies (2023–2025) confirm that intercropping mungbean (*Vigna radiata* L.) with maize (*Zea mays* L.) continues to deliver higher yields, improved nutrient uptake, and better land-use efficiency compared to monocropping. Trials in Cambodia, Iraq, and arid-irrigated regions show yield gains of up to 20–30% and stronger economic returns Akchaya et al., 2025. Intercropping mungbean (*Vigna radiata* L.) with different maize is another method of a profitable alternative production strategy available to farmers, thus improving agricultural productivity (Assefa et al., 2025). Intercropping can help reduce soil erosion and maintain soil fertility, especially when legumes are grown with cereal crops. Moreover, mungbean (*Vigna radiata* L.) with different maize varieties enriches the soil with nitrogen (N) because of the legumes' ability to fix nitrogen through the nitrogen-fixing bacteria (Rhizobia) found in root nodules (Favero et al., 2021). The inoculation of bean seeds with Mykovam® and plant symbiosis can promote plant water and nutrient uptake and improve plant growth, but differences exist among various plants when mycorrhizal fungi colonize plant roots and influence plant growth. Mycorrhizal symbiosis may play an important role in transferring water and nutrients between maize and mungbean in the intercropping system (Yuliana et al., 2021).

Fertilizers are used in much of sub-Saharan Africa and the Philippines, although the quantities applied are insufficient to meet crop demands (Dimkpa et al., 2023). This calls for more on-the-spot and hands-on techniques and strategies, and the use of farmer-available resources. Soil fertility depletion is the major limiting factor in crop production. Smallholder farmers in tropical regions continue to suffer from acute food shortages, hunger, and extreme poverty attributed to declining crop harvests and grain quality due to low soil fertility (Dimkpa et al., 2023). Low soil fertility in the tropics is a result of continued mining of soil nutrients, particularly N and P, without adequate replenishment, accelerated soil erosion, and leaching. In these regions, there is low usage of fertilizers due to unavailability and high prices, which are above the purchasing power of many smallholder farmers in the area (Amankwah et al., 2024). Continuous mono-cropping of cereal crops without fallowing has worsened the situation (Amankwah et al., 2024).

Extreme adverse climatic conditions in tropical regions have also contributed immensely to hunger and poverty. These adverse climatic conditions, such as increased evapotranspiration, greater terminal heat stress, drier soils, and shorter growing seasons, destroy crops that are not adapted to these stresses, hence decreasing agricultural productivity and profitability, leading to more food insecurity and poverty (Lesk et al., 2022).

Loss of soil fertility is a serious problem affecting national food security. Improving soil fertility could trigger rural and national economic development, achieve food security, and improve farmers' "standards of living at the same time mitigating environmental degradation" (Naik et al., 2025). The ability of legumes to fix atmospheric N makes them excellent components within various farming systems in tropical regions. They provide residual N and reduce the need for mineral N fertilizers by associated non-legumes (Kumari et al., 2022; Karanja et al., 2014). Mungbean is among the superior grain legumes in the cropping systems of tropical countries and fixes quite a substantial amount of N. Its capacity to fix atmospheric N reduces inorganic N inputs in low-input farming systems. Moreover, it has high economic returns and nutritional values, which may positively impact the health of the farmer's households, especially children, the disadvantaged, and poor rural farmers. Thus, mungbean intercropped maize holds great potential to combat problems of food insecurity and poverty in rural farming communities in Liberia (Wesseh, C. W, 2024).

Grain legumes, through biological nitrogen fertilizers (BNF), offer complementary, less costly, manageable, and viable soil fertility enhancement strategies for resource-poor farmers to realize improved and extended grain yields and sustained farm productivity and profitability (Mucheru-Muna et al., 2003). Besides, the legume cereal-based intercropping structure generally extends the land-use efficiency and economic return over monocrop legumes (Tamiru, W. (2022). Intercropping systems additionally offer greater yield stability and the reduction of crop failures than sole cropping systems (Weih et al., 2021).

Legumes can also grow and develop in poor soils when there is no longer adequate fixed N to help different kinds of plants. After harvesting legumes, decaying roots left in the soil may release natural and or organic nitrogen compounds for uptake by the next generations of plants. Rhizobium is the most well-known group of bacteria that acts as the principal symbiotic N fixer. These micro-organisms can affect the roots of leguminous plants, leading to the formation of nodules where the actual N fixing takes place. The bacterium's enzyme system supplies a constant source of reduced nitrogen to the host plants, and the plants furnish nutrients and energy for the activities of the bacterium, and about 90% of legumes can become nodulated (Raza et al., 2020). Legume N fixation starts with the formation of the nodules. A frequent soil bacterium, Rhizobium, penetrates the roots and multiplies within the cortex cells. The plant supplies all the imperative nutrients and energy for the bacteria. Within a week after infection, small nodules are visible to the naked eye. In the field, small nodules can be seen 2-3 weeks after planting, depending on the legume's species used and germination conditions. Nodules on annual legumes such as beans, peanuts, and soybeans are spherical and can reach the dimensions of a large pea; nodules on annuals are short-lived and will be replaced constantly during the growing seasons (Maluki, M. (2023).

At the time of pod fill, nodules on annual legumes normally lose the potential to fix nitrogen because the plant feeds on the developing seeds rather than the nodules. Beans will usually have fewer than one hundred nodules per plant, soybeans will have several hundred per plant, and peanuts may additionally have up to one thousand or more on the well-developed plant. (Lindeman, 2003).

Phosphorus is important in enhancing plants' growth and development through proper root development at early growth stages, leading to efficient utilization of soil water and nutrients. It also increases nodulation and growth in legumes (Chen et al., 2023). Thus, low levels of P in the soil limit plants' capacity to fix N, hence reducing the yield potential of the crop or component crops in an intercropping system (Gong et al., 2025). The natural ability to fix N makes grain legumes necessary crops for smallholder farmers, and a key to Integrated Soil Fertility Management (ISFM). N deficiency is a consequence of its continued depletion from the soil pool through processes such as volatilization, leaching, and, most importantly, removal of N-containing harvest products and crop residues from the Farm (Udvardi et al., 2021). The N reserve of agricultural soils must, therefore, be replenished in many instances to preserve a sufficient level for crop production.

Increasing interest is being given to harnessing the workable benefits from renewable sources of plant nutrients. Thus, biological nitrogen fixers (BNFs) hold tremendous promise for smallholder farmers in sub-Saharan Africa and the Philippines. BNF can reduce or eliminate farmers' needs for commercial mineral N. Agro-experts have therefore become aggressive in pushing BNF, which is once in a while free and is convenient to learn, as the first-class route to follow for Africa and the Philippines. The method includes crop rotations or intercropping legumes with cereals (MATHOBO, D. N. 2023). However, grain legumes (i.e., soybean, common beans, cowpea, groundnut, chickpea, and pigeon pea) are often included as minor intercrops in fields of cereals in most smallholder cropping systems. This is because smallholder farmers operate below numerous socio-ecological constraints that restrict the productivity of legumes and farmers' potential to scale up the integration of legumes into their farming systems (Das *et al.*, 2026).

Growing legumes and cereals such as mungbean and maize as intercrops for food production is famous among subsistence farmers in the tropics and semi-arid regions. This cropping method is extensively adopted by farmers across Africa as a means of diversifying food sources and as a fail-safe measure when one crop fails (Scott *et al.*, 2022). The system offers advantages in terms of greater yield stability, better total crop productivity, and profitability in contrast with the monocropping system, greater land-use efficiency, and elevated competitive ability of crops towards weeds (Ahmed *et al.*, 2013). Moreover, legumes are sources of high protein for food and feed (Sonta, M., & Rekiel, A., 2020). It additionally enhances N uptake and the plant's crop capacity to withstand drought. BNF plays a vital role in the N budget of cereal/legume mixed culture.

Improving the intercropping system of mungbean and maize production among smallholder farmers in rural areas of tropical regions has the potential to reduce food insecurity and enhance income generation of the rural communities, leading to improvement of the nation's GDP and advancement in its economic performance in the global world (Takhumova, O. (2020). This research is useful to small-scale farmers in tropical regions through the utilization of resources acquired from intercropping to enhance soil fertility and improve mungbean and maize production in the region. Farmers can now benefit from improved production efficiencies due to the utilization of locally available N inputs through fixation. Intercropping mungbean and maize enabled the

resource-constrained farmers to achieve high productivity and profitability of the farmlands due to greater land-use efficiency in intercropping than in sole-cropping schemes.

Therefore, the need to develop management options geared towards enhancing soil fertility, increasing grain quality, and improving agricultural productivity and profitability remains to be relevant, with the use of cheap and locally available farmer resources, which are easy to adopt within the farmer's capability and development of inoculation. The research sought to evaluate the impact of different cropping systems on the growth, yield, and profitability of Pag-asa 7 Mungbean Variety Inoculated with Mykovam<sup>®</sup>

## MATERIALS AND METHODS

### Time and Place of the Research

The research was conducted at the Central Experiment Station (CES), University of the Philippines, Los Baños, College, Laguna, Philippines, from December 8, 2020, to February 8, 2022.

The total monthly rainfall distribution, relative humidity, and temperature (maximum and minimum) during the experiment were obtained from the National Agrometeorological Station, University of the Philippines, Los Baños, College, Laguna.

### Experimental Design and Treatments

The research has three variables: cropping systems (mono-crop and intercrop), mungbean variety (Pag-asa 7 Mungbean), and Mykovam<sup>®</sup> inoculations (with and control/without). The research was laid out in a Randomized Complete Block Design (RCBD) with three replicates. Mungbean was intercropped in three open-pollinated maize varieties, namely: IPB 6, IPB 1910, and Los Baños Lagkitan.

### Experimental Area

The experimental area occupied 1,263.5 m<sup>2</sup>; each block measured 45.0 m × 10.5 m (441 m<sup>2</sup>) while each plot was 6.0 m × 5.0 m (30.0 m<sup>2</sup>).

### Planting

Mungbean were intercropped between the rows of maize in each treatment except the control (mono-crop) with 12 rows of mungbean, each row was 0.5m apart and 0.25m between hills. The total number of mungbean plants under mono-crop mungbean is 80,000 plants per hectare. There was a total of 12 rows with 20 plants per row constituting a plant population of 240 plants per plot, 80,000 plants per hectare. For the intercropping, mungbean were sown in between rows of maize.

### Crop Management

#### Varieties Used

Pag-asa 7 mungbean variety was released in 1989. It has shiny green seeds and slender pods, which are almost parallel to the ground; moderately resistant to *Cercospora* leaf spot. It thrives in acidic soil; it is drought-tolerant and a good nitrogen fixer (IPB, 1989). Pag-asa 7 mungbean was intercropped in IPB Var 6, an open-pollinated white variety, which is quality protein maize (QPM) with a lysine content of 0.374%, which is 66.2% higher than normal maize (0.225%). IPB 1910, an open-pollinated white maize variety, is highly adapted to agro-climatic conditions prevailing in the major maize-growing areas in Luzon and Los Baños Lagkitan, an open-pollinated white glutinous maize variety grown primarily for table use, native delicacies, and kornik.

#### Fertilizer application

The rate of fertilizer applied was based on the recommended rates of 80, 60, and 60; and the correct amounts of fertilizer were computed and applied (Wang et al., 2024). The recommended rate is expressed in kilograms N, P, and K per hectare, respectively.

## Inoculation

Mykovam® is a fungi-based bio-fertilizer developed by UPLB-BIOTECH. This mycorrhizal inoculant is composed of spores, infected roots, and other infective propagules of endomycorrhizal fungi. Mykovam® was applied as a slurry to the seeds of **Pag-asa 7** mungbean and sprayed for the second and third applications. Nine packs per hectare (each pack contains 300 grams, a total of 2,700 grams) were used. At sowing, seven packs (2,100 grams) were coated onto slightly moistened seeds. The second application was sprayed (dissolved 300 g or 1 pack to 32 L of water) 10 days after sowing (DAS), and the third application was sprayed (dissolved 1 pack to 32 L of water) at 20 days after sowing (DAS).

## Weeding and thinning

Seedlings were thinned to one plant per hill to obtain the desired plant population of 7-15 DAS and emergence. Weeding was done three (3) times, at 10, 15, and 20 days after sowing (DAS).

## Irrigation

Supplemental irrigation was provided to the plants when needed. Water stress was avoided as much as possible.

## Pest Management

Synthetic insecticide at 0.5kg per hectare was applied in furrows along with fertilizers before planting for initial control of insect pests. An additional application of Synthetic insecticide was made in the maize at 30 days after sowing (DAS) for the proper control of green vegetable bugs, and Thresholds: Pod-sucking bug. Synthetic insecticide was sprayed alternatively on the mungbean at 45 days after sowing (DAS).

## Harvesting

Mungbean was harvested manually, and priming was done three times; the pods were shelled manually at 60, 68, and 76 days after sowing (DAS). Mungbean was harvested when the pod became dark brown to black. Mungbean matures after 62-74 days from seedlings. Grain moisture content was determined after sun drying for 14 days (two weeks) using a steinlite tester.

## Data Gathering

The data collection on plant height was done at 15, 30, and 45 days after sowing (DAS).

## Agronomic parameters

Plant height (cm), 10 plants were selected randomly and tagged from each plot. The plant's height was measured from the soil surface to the tip of the fully expanded leaves 15 days from 30 days after sowing (DAS) and at the tip of the tassel at the flowering stage.

## Physiological parameters

**Leaf area index (LAI).** The LAI is the total functional leaf area per unit ground area. Three plants were selected randomly from each plot. The LAI was measured at 75 days after sowing (DAS), at the end of the entire experiment, to avoid destructive sampling.

The LAI was calculated as follows:

$$\text{LAI} = \frac{\text{Total leaf area}}{\text{Total Ground area}}$$

Total Ground area

**Light attenuation down the canopy.** This was measured in the field at different canopy levels: upper leaf, middle leaf, and lower leaf levels. This parameter was determined using the model of the light meter brand MQ-303 and used the formula by (Díaz-Ambrona *et al.*, 1998)

$$I = I_0 e^{-kL}$$

Where:

$I_0$  = is the irradiance above the crop canopy

$I$  = irradiance at a point in the canopy above which there is a leaf area index of  $L$ . Both  $I_0$  and  $I$  measured horizontally disposed sensors, and  $k$  and  $L$  are dimensionless.

$S = e^{-k}$  is used in place of  $k$  (as the natural logarithm, linear attenuation factor).

Three Canopy layers were measured: above canopy, middle level canopy, and below canopy. From the surface, 12cm high, and the upper part from the lower was divided into two to indicate the middle and upper layers (Upper = Middle).

### Yield Parameters

The mungbean samples for yield parameters are similar to those that were tagged for plant height samples.

**Number of pods per plant.** The number of pods was counted and recorded, and the average number of pods per plant was calculated.

**Seeds per pod.** The number of seeds per pod was counted, and the average number of seeds per pod was calculated.

**Pod length (cm).** The pod length was recorded, and the average per plant was calculated.

**Weight of pods + seeds (g).** The weight of pods plus seeds was recorded, and the average per plant was calculated.

**One thousand seeds' weight (g).** One thousand seeds were counted and weighed.

**Total yield (14% moisture content, Mg m<sup>-2</sup>).** This was converted to the total weight from 4m<sup>2</sup> to one hectare. All yields were expressed in dry seeds 14% MC basis and estimated at 28-30% MC during harvest, using the following formula:

$$Y = Y_1 - [(100 - MC) / 86]$$

### Land Equivalent Ratio (LER) and Yield Reductions

The LER analysis of intercrop was done in terms of the nutrient utilization and efficiency of N, P, and K. The LER was calculated to see if there were significant differences in yield between the intercropped and monocrop. LER is the sum of the fraction of intercrop yield divided by mono-crop yield. This parameter was measured after harvest in each plot. The LER was calculated using the formula:

$$LER = \frac{Y_{ij} + Y_{ji}}{Y_{ii} \quad Y_{jj}}$$

Where:

$Y_{ij}$  = Yield of maize under varying varieties of intercropping conditions

$Y_{ji}$  = yield of mungbean under intercropping conditions

$Y_{ii}$  = yield of maize under mono-crop conditions

$Y_{jj}$  = yield of mungbean under mono-crop conditions

Yield reductions (%) = (Actual yield-theoretical yield/inter-crop) \* 100

## Productivity and Profitability of Mungbean Intercrops with Three Maize Varieties

**Profitability.** This was calculated using the indicators Gross Return (GR), Net Income (NI), the total cost of Production (TCP), and benefit-cost ratio (B/CR), using the formula:

$$NI = GR - TCP \text{ and } BCR = GR / CC$$

**Grain-quality crude protein.** One thousand seeds from each treatment were ground, and the crude protein content from them was taken to the Laboratory for analysis.  $NH_4^+$  content was calculated (Kjeldahl Method), Official Methods of Analysis of AOAC International, 16th edition.

### Statistical Analysis

The homogeneity and normality of the data were tested using Bartlett's, Levene's, and Shapiro-Wilk's tests, respectively. The data were subjected to ANOVA using the International Rice Research Institute (IRRI) Statistical Tool for Agricultural Research (STAR). The relationship between the selected parameters was determined using correlation and regression analysis. Treatment means were compared using Tukey's Honest Significant Difference (HSD).

## RESULTS AND DISCUSSION

### Agro-meteorological Data

#### Rainfall Distribution

It was shown in Figure 3 that there were intermittent occurrences of rainfall, especially from the first day to 25 days after planting (DAP). However, the rainfall from 26 DAP to 77 DAP was sporadic, and the average rainfall was 2.5-7.9 mm only, which was not sufficient for the maize crop to grow. Furthermore, at the onset of the reproductive stage of mungbean at 50 days after sowing (DAS), rainfall was almost very rare, and the reproductive stage of the crop is very critical to determine yield; therefore, supplemental irrigation was done.

#### Rainfall Distribution Mean Daily Temperature

Mungbean as a leguminous plant optimally performs under a temperature range of 30-35°C, above which the plant may be adversely affected due to extreme temperature. Figure 1 shows that the daily temperature was below the optimum range for the entire growth period. This suggested that the crop did not experience heat stress.

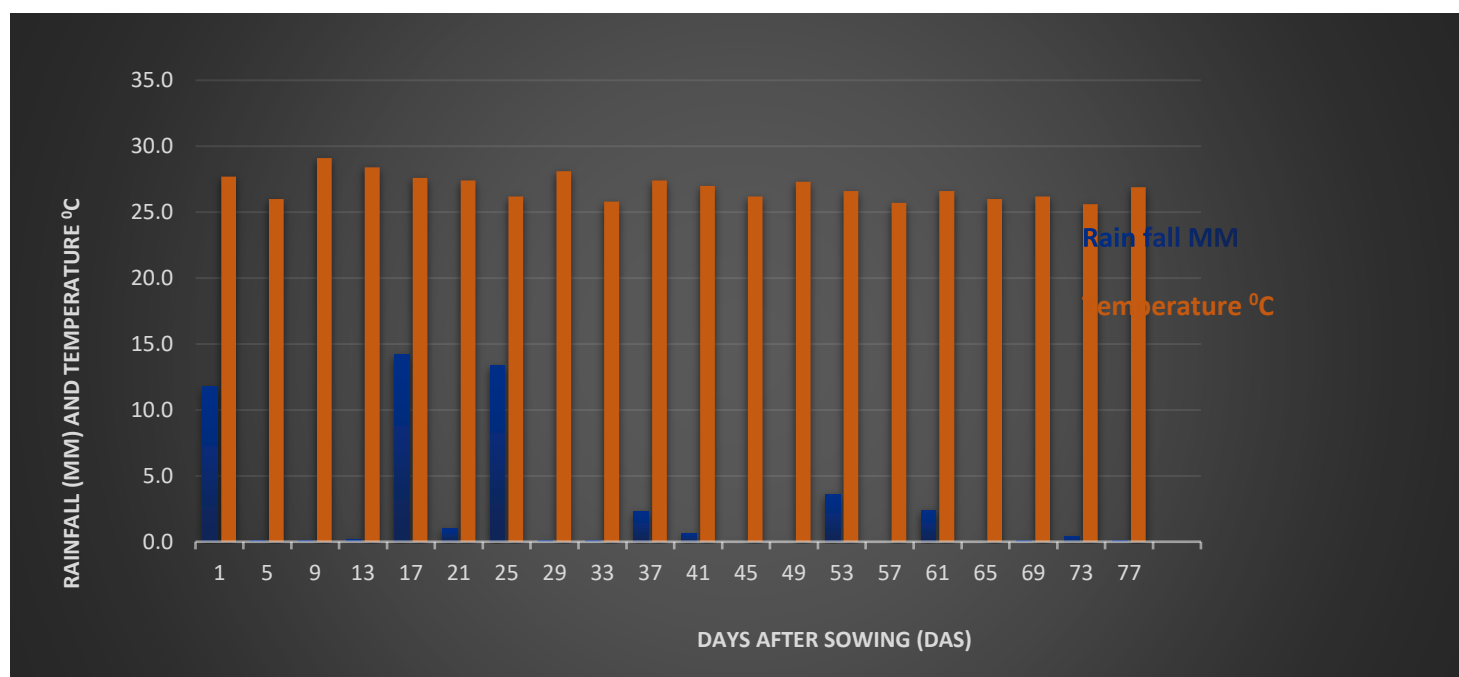
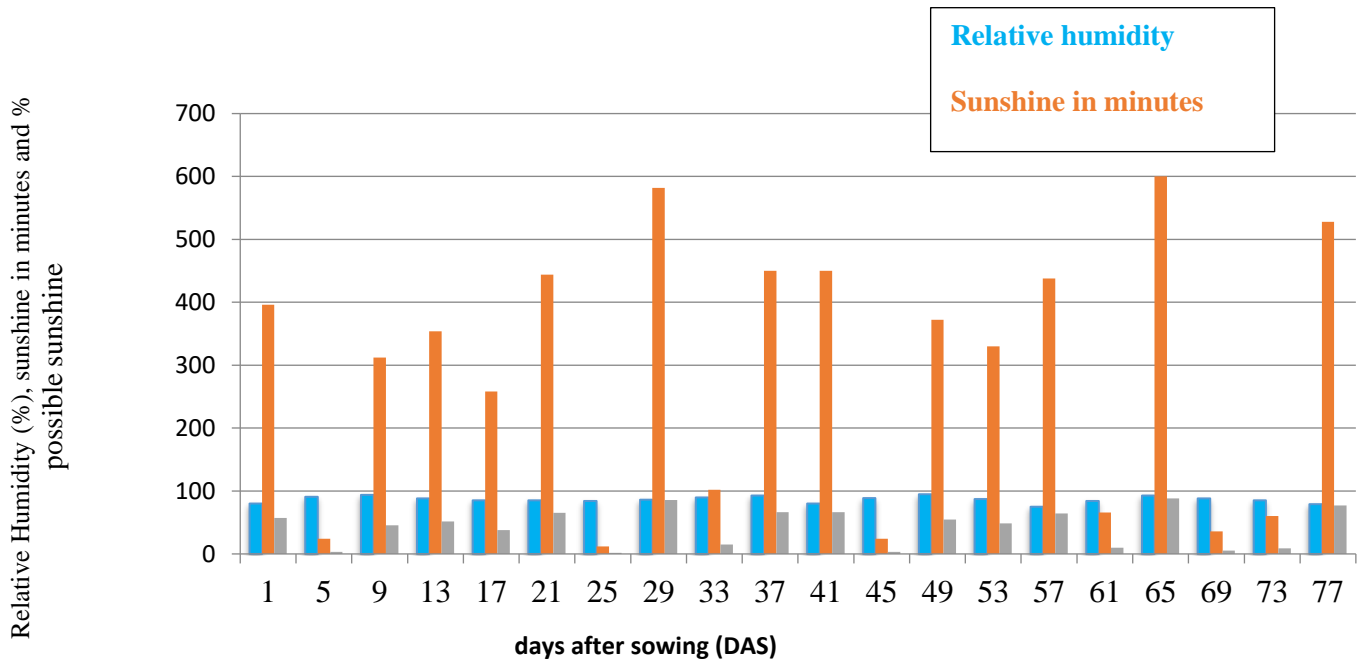


Figure 1. Rainfall distribution and temperature °C for the whole growth period of maize and mungbean

**Sunshine (% possible), Relative Humidity (RH), and Sunshine in minutes**

The relative humidity influenced the crop evapotranspiration. Figure 2 shows the range of RH at 78-95%, which presupposes that the surrounding air was very saturated with moisture, hindering the crop's evapotranspiration. Meanwhile, Figure 2 also showed the sunshine distribution in minutes across the entire growing season. The solar radiation received by the maize crop was sufficient for possible high photosynthetic activities starting from 15 days after sowing (DAS) onwards. Sunshine has tremendously increased, which is very beneficial for the growth and development of the maize crop.



**Figure 2. Sunshine (% Possible), Relative Humidity, and Sunshine in minutes for the whole growth period of the mungbean**

**Abiotic Factors, Soil Fertility Parameters, and Agro-Metrological Data Soil Testing Before and After Harvest**

The soil pH was significantly influenced by the interaction between the cropping system, fertilizer applications, and inoculation Tables 1 and 2. Mungbean and Intercropped maize and inoculation accounted for the highest increase, and this could be due to the moisture level retained. There was about 11% increase in soil pH after harvest. Additionally, there are climatic factors that influence soil pH, such as temperature, rainfall, carbon dioxide concentration in dissolved water, etc. The Organic matter content before and after harvest was significantly affected by the cropping system Tables 1 and 2. Soil organic matter was also influenced by the soil moisture content, water saturation, soil acidity, and vegetation and biomass productions across treatments. Mungbean intercropped in Los Baños Lagkitan produced the highest biomass. The soil nitrogen content was significantly influenced by the interaction between the cropping systems in Tables 1 and 2. Some agro-climatic conditions also influenced the nitrogen content across treatments, such as rainfall, temperature, moisture level, fertilizer application, and soil aeration as affected by organic matter. Data support the previous knowledge that legumes such as mungbean can improve N content of the soil due to their ability to fix N and their association with N-fixing bacteria; those with legumes have greater N content than those treatments without mungbean. The soil potassium levels were affected and influenced by the uptake, interaction between cropping systems, and inoculation Tables 1 and 2. Some other factors significantly influenced the level of potassium after harvest, which include soil pH, soil moisture content, soil organic matter, cation exchange capacity, and tillage. The phosphorus level in soil was influenced by cropping systems in Tables 1 and 2. Some physical, chemical, and climatic characteristics influence the level of phosphorus level in the soil, such as soil pH, organic matter content, temperature, fertilizer applications, and moisture retention in the soil. Data showed that there were only slight differences in P levels in the soil except under intercropping without inoculation.

**Table 1. Results of soil analysis before planting of mungbean (*Vigna radiata* L.) and Maize (*Zea mays* L.) as affected by maize varieties, cropping systems, and inoculation**

Laboratory No	BEFORE PLANTING					
	Sample Code	pH	Om %	N 5% OM	P mg/kg (Olsen)	K cmol/kg/soil
S-2674	Monocrop mungbean without inoculation	6.3	3.45	0.1725	102	2.18
S-2675	Monocrop mungbean maize with inoculation	6.2	3.41	0.1705	111	2.24
S-2676	Monocrop maize without inoculation	6.2	3.68	0.184	115	2.11
S-2677	Monocrop maize with inoculation	6.3	3.58	0.179	107	2.43
S-2678	Intercropped maize and mungbean without inoculation	6.2	3.66	0.183	166	1.47
S-2679	Intercropped maize and mungbean with inoculation	6.2	3.32	0.166	108	2.18

**Table 2. Results of Soil analysis after harvest of mungbean (*Vigna Radiata* L.) Maize (*Zea mays* L.) is affected by maize Varieties, cropping systems, and inoculation**

AFTER HARVEST						
Sample Code	pH	Om %	N 5% OM	P mg/kg (Olsen)	K cmol/kg/soil	
Monocrop mungbean without inoculation	6.5	3.52	0.432	123	2.27	
Monocrop mungbean with inoculation	6.4	3.57	0.293	117	2.29	
Monocrop maize without inoculation	6.4	3.76	0.473	120	2.34	
Monocrop maize with inoculation	6.4	3.42	0.231	118	2.63	
Intercropped maize and mungbean without inoculation	6.7	3.43	0.342	173	2.27	
Intercropped maize and mungbean with inoculation	6.9	3.97	0.487	127	2.72	

**Agronomic Parameters**

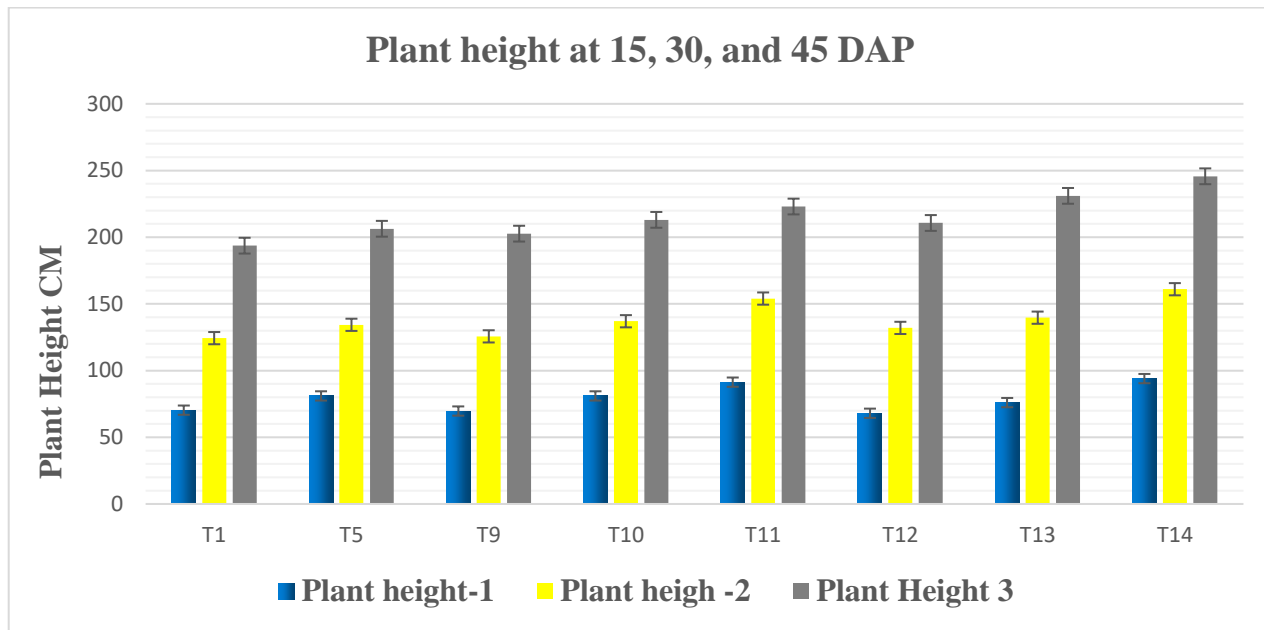
It was hypothesized that intercropping mungbean with maize and with the application of Mykovam® as an inoculant under different cropping systems would have better growth, a high yield advantage, and better grain quality. The result of this research did support the hypothesis that cropping systems, Pag-asa 7 mungbean, and inoculation impact the yield and grain quality of mungbean (Pag-asa 7 mungbean). Inoculated Pag-asa 7 mungbean mono-crop, and when intercropped in IPB Var 6 with inoculation, resulted in greater growth, higher yield, and grain quality. Higher yield was associated with a variety with uniform height (Lavelah et al., 2021); hence, height is a good indicator. LAI is associated with the cropping system and Pag-asa 7 mungbean, as it is an index of photosynthetic rate and is described as the achievable harvesting surface per unit area. (Lavelah et al., 2021).

***Plant Height of Mungbean Monocrop and Intercrop under Varying Maize Varieties and Mykovam® Inoculation at 15, 30, and 45 DAP***

There was a significant difference between the monocrop and intercrop mungbean (Figure 3). Monocrop mungbean was shorter than when used as an intercrop with maize, except when intercropped with IPB Var 6, which showed similar height to the monocrop mungbean. Mungbean intercropped with IPB Var 1910 without inoculation is similar to mono-crop mungbean with inoculation, but was shorter when inoculated. There was a substantial difference between the monocrop and intercrop mungbean. The height of the maize varieties considerably influenced the height of the mungbean when used as an intercrop. Mungbean plants intercropped with Los Baños Lagkitan were the tallest. The shorter the maize variety, the shorter the mungbean height as affected across the treatments at 15, 30, and 45 days after sowing (DAS). Mungbeans under intercropping and inoculation were taller compared to those without inoculation, except for those intercrops with IPB var 1910, which is similar to monocrop mungbean with inoculation. There was a consistent increase in the height of mungbean intercropped with Los Baños Lagkitan, which exhibited the tallest characteristics of the maize varieties, followed by the IPB 1910, as the second tallest variety. Mungbean mono-crop without inoculation

exhibited the shortest across the treatments. Those inoculated under intercrop showed taller mungbean compared to those intercrops without inoculation.

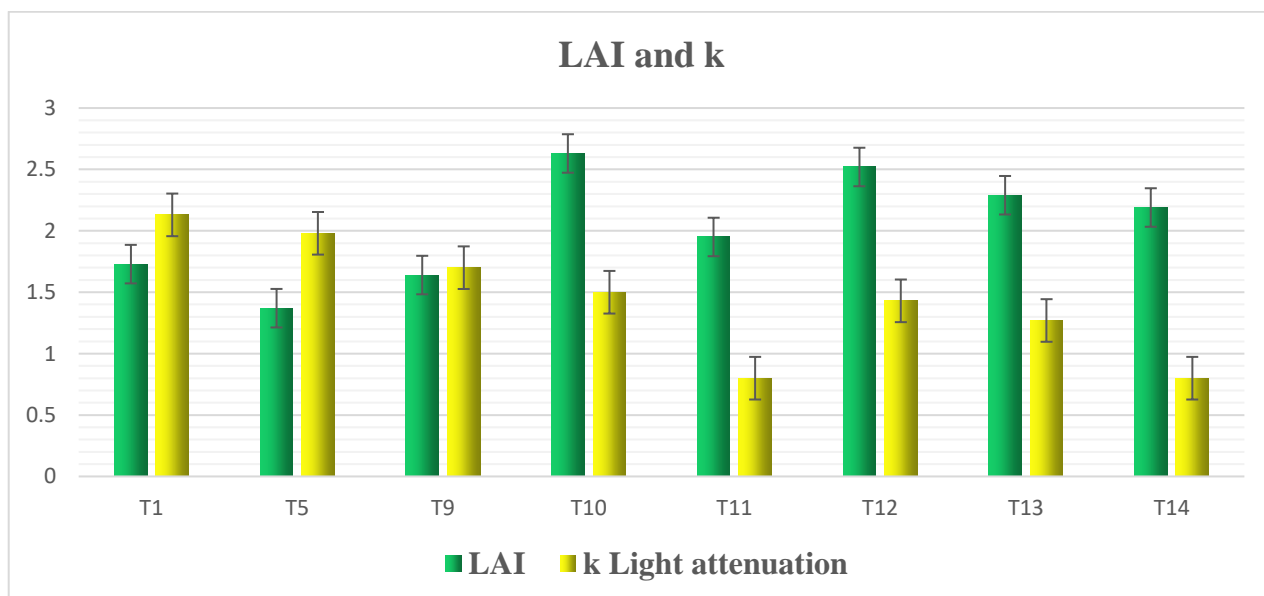
**Figure 3. Effect of maize variety, cropping systems, and inoculation on plant height of mungbean at 15, 30, and 45 DAS, (SE = 1.04), (SE = 1.53), and (SE = 2.12)**



**Leaf Area Index (LAI) and k Light attenuation of Mungbean**

**Under Different Cropping Systems and Mykovam® Inoculation at 60 days after sowing (DAS)**

Mungbean mono-crop had the least LAI, either with or without inoculation. There were hardly any significant differences in the leaf area index among the different cropping systems and inoculation, except in the intercrop without inoculation, when the LAI of the mungbean and intercropped IPB Var 6 was significantly less than that of those that were intercropped with IPB Var 1910. The k light attenuation varied across different mungbean cropping systems and maize varieties, and there were significant differences and interactions between monocrop and intercrop, inoculation, and varieties. Monocrop mungbean had the highest k light attenuation among the intercropping systems. IPB Var 6, which is the shortest among the maize varieties, had the highest k light attenuation, while Los Baños Lagkitan had the lowest k light attenuation, which was the tallest of the maize varieties.



**Figure 4. Effect of mungbean cropping systems, maize varieties, and inoculation on LAI at 60 DAS.**

### Yield Parameters of Mungbean Intercropped Under Varying Maize Varieties and Inoculation

The number of pods per plant was significantly influenced by the cropping system and maize varieties (Table 3), whereby mono-crop mungbean with inoculation had the highest average number of pods per plant. This was accompanied by monocropped mungbean without inoculation. Intercropped IPB Variety 6 additionally led the varieties with the highest number of pods per plant, and this is due to the plant height. Both the taller and shorter plant height significantly influenced the number of pods per plant. The pod length was influenced by maize varieties, cropping systems, and inoculation. Under a monocropping system, mungbean inoculated with Mykovam<sup>®</sup> produced longer pods than those without inoculation. Under intercropping systems, those planted with IPB Var 1910 and Lagkitan, regardless of inoculation treatment, had shorter pods compared with those under monocropping. Mungbean intercropped with IPB Var 6, regardless of inoculation treatment, had longer pods and were similar to those of monocropped mungbean inoculated with Mykovam<sup>®</sup>. The pod weight was significantly influenced by the cropping system. Mungbean intercropped in IPB Variety 6 with and without inoculation had the heaviest pod weight, and this is due to the height of the variety and light penetration down the canopy. The number of seeds per pod was significantly influenced by the pod length; the longer the pod, the greater the number of seeds. Monocropped mungbean had a similar number of seeds regardless of inoculation. Under intercropping, whether inoculated or not, the highest number of seeds per pod was those intercropped with IPB Var 6, which also accounted for the longest pod. The 1000 seed weight was significantly affected by the interaction between varieties, cropping systems, and inoculation. Under monocropped mungbean, those inoculated with Mykovam<sup>®</sup> had the highest seed weight. Under intercropping, those planted with IPB Var 6 produced heavier seeds than the other two varieties, regardless of whether they were inoculated or not.

**Table 3. Yield parameters of mungbean (*Vigna radiata* L.) as affected by maize varieties, cropping systems, and inoculation**

TREATMENT	Mungbean YIELD PARAMETERS				
	No of pods <u>Plant<sup>-1</sup></u>	Pod Length (cm)	Pod weight (g)	No of Seeds <u>pod<sup>-1</sup></u>	1000 seed <u>weight (g)</u>
<b>T1</b>	54.0 b	29.70 b	15.00 b	7.33 ab	77.67 ab
<b>T5</b>	74.67 a	32.63 a	17.33 a	8.33 a	82.33 a
<b>T9</b>	42.67 cd	32.83 a	15.33 b	7.00 abc	80.00 a
<b>T10</b>	41.00 d	24.43 c	12.00 c	5.67 cd	70.00 abc
<b>T11</b>	47.00 c	20.63 d	11.33 c	4.33 d	64.33 c
<b>T12</b>	45.00 cd	33.33 a	17.33 a	6.67 bc	72.67 abc
<b>T13</b>	35.67 e	22.03 cd	11.67 c	5.67 cd	66.00 bc
<b>T14</b>	47.00 c	20.50 d	11.67 c	5.00 d	72.00 abc
<b>Mean</b>	<b>48.37625</b>	<b>27.01</b>	<b>13.9575</b>	<b>6.25</b>	<b>73.125</b>
Significance					
Cropping System (CS)	**	**	**	**	**
Inoculation (I)	*	*	*	*	*
Blocks (B)	Ns	Ns	ns	Ns	ns
Var x CS x I	**	**	**	**	**
CS X I	**	**	**	**	**
Var x B	ns	Ns	ns	Ns	ns
<b>HSD 0.05</b>					

Means followed by different letters within each column are significant at alpha =0.05

\*= significant, \*\* highly significant, ns not significant

## Yield and grain quality of mungbean (*Vigna radiata* L.) under different cropping systems and Mykovam® inoculation

Grain yield at 14% MC of monocropped mungbean with inoculation had the greatest seed yield (1.73 Mg ha<sup>-1</sup>) in contrast to other cropping systems, even though the monocropped mungbean without inoculation (1.60 Mg ha<sup>-1</sup>) did not significantly differ. Mungbean yield did not significantly differ when intercropped with IPB Variety 6 with or without inoculation, but considerably differed when intercropped with Los Baños Lagkitan.

### Yield parameter

Mungbean, on the other hand, performed better under mono-crop conditions with inoculation. The yield of mungbean with inoculation was 1.73 Mg ha<sup>-1</sup>, whereas the monocrop non-inoculated had 1.60 Mg ha<sup>-1</sup>. However, the yield of mungbean intercropped with different maize varieties responded differently depending on the characteristics of the maize variety. Overall, though, mungbean reduced its yield under intercropping. The greatest yield reductions were under intercropping with UPLB Lagkitan with and without inoculation at 36.00% and 18.12%, respectively. This could be due to the tall stature of Lagkitan, which increased the shading of the mungbean, and as a response, the mungbean also grew taller in these treatments and had fewer photosynthates left for grain filling.

### Cost-benefit analysis of mungbean (*Vigna radiata* L.) and maize (*Zea mays* L.) varieties intercropped under Mykovam® inoculation

The highest gross return (GR) in mungbean was obtained in Monocrop Mungbean inoculated with Mykovam® ₱ 123,217 ha<sup>-1</sup>, and the lowest gross return (GR) was obtained in mungbean intercropped with Los Baños Lagkitan ₱ 51,239 ha<sup>-1</sup>. The highest total cost of Production (TCP) was obtained in monocropped mungbean, and Mykovam® inoculation, ₱ 76,549 ha<sup>-1</sup> and the lowest cost of Production (CP) was obtained in mungbean intercropped with Los Baños Lagkitan, ₱ 33,716 ha<sup>-1</sup>. The highest net return (NR) was obtained in monocropped mungbean without Mykovam® inoculation, ₱ 53,168 ha<sup>-1</sup>, and the lowest net return (NR) was obtained in mungbean IPB 1910 intercropped ₱ 16,770 ha<sup>-1</sup>.

The increase in the cost of cultivation in the intercropping system was due to the additional cost of planting materials, seeds, and labor; the net return of maize obtained from the intercropping system was substantially higher than that of the monocropping system due to the diversification, complementarity, and resource use efficiency that exist in the intercropping system. Using an intercropping system, you can assure an ecological balance and better use of resources. Crops yield increases with intercropping due to higher growth rate, reduction of weeds, pests, and diseases, and more effective use of resources. Pest and disease damage in intercropping is less than in monocropping systems Duncan *et al*, 2018). The research postulates that intercropping systems are more productive and beneficial than monocropping systems.

**Table 4. Cost-benefit analysis of mungbean (*Vigna radiata* L.) and maize (*Zea mays* L.) varieties intercropped under Mykovam® inoculation**

CROPPING SYSTEM	GROSS RETURN (Php ha <sup>-1</sup> )			TOTAL COST OF PRODUCTION (Php ha <sup>-1</sup> )			NET RETURN (Php ha <sup>-1</sup> )			BCR
	Maize	Mungbean	Total	Maize	Mungbean	Total	Maize	Mungbean	Total	
T1	---	118,600	118,600	-	65,432	65,432	-	53,168	53,168	1.2
T2	82,543	---	82,543	61,267	-	61,267	21,276	-	21,276	1.35
T3	80,218	---	80,218	69,752	-	69,752	10,466	-	10,466	1.15
T4	79,967	---	79,967	67,965	-	67,965	12,002	-	12,002	1.17
T5	---	123,217	123,217	-	76,549	76,549	-	46,668	46,668	1.6
T6	82,543	---	82,543	68,654	-	68,654	13,889	-	13,889	1.2
T7	79,876	---	79,876	57,987	-	57,987	21,889	-	21,889	1.4
T8	79,789	---	79,789	56,654	-	56,654	23,135	-	23,135	1.4
T9	68,629	53,217	121,846	33,231	35,219	68,450	35,398	17,998	53,396	1.9
T10	63,769	54,987	118,756	37,562	38,217	75,779	26,207	16,770	42,977	1.6
T11	62,232	51,239	113,471	31,918	33,716	65,634	30,314	17,523	47,837	1.72
T12	67,632	52,987	120,619	33,251	34,982	68,233	34,381	18,005	52,386	1.8

T13	61,976	57,398	119,374	32,345	34,347	66,692	29,631	23,051	52,682	1.8
T14	60,986	56,987	117,973	34,256	36,123	70,379	26,730	20,864	47,594	1.7
<b>TOTAL</b>	<b>807,160</b>	<b>568,632</b>	<b>1,238,792</b>	<b>584,842</b>	<b>354,585</b>	<b>939,427</b>	<b>285,318</b>	<b>214,047</b>	<b>499,365</b>	

The price of maize during harvest is 18 Php/kg (Institute of Plant Breeding price tag), and mungbean is 95 Php/kg (local wet market price tag). The cost of cultivation includes irrigation, labor, land preparation, land rental, inoculant, fertilizer, pesticides, chemicals, seeds, and equipment used.

BCR: Benefit Cost Ratio

**Productivity and Profitability of Mungbean (*Vigna radiata* L.) and Maize (*Zea mays* L.) Varieties and Intercropped with Mykovam® Inoculation**

**Land equivalent ratio.** Mungbean intercropped with Los Baños Lagkitan without inoculation achieved the highest LER of 1.05, which indicates 11.7% better land utilization efficiency and higher productivity compared to IPB Variety 6 intercropped with mungbean without inoculation at 0.94. Yield reduction in mungbean is higher compared to maize, with 82.25% 78.53%, respectively. The result showed the complementarity in maize and mungbean and the yield advantage with LER values greater than one (1).

**Table 5. Yield and yield reduction due to intercropping, and land equivalent ratio as affected by maize-mungbean intercropping schemes**

CROPPING SYSTEM	Grain Yield of Maize (Mg ha <sup>-1</sup> )	Yield Reduction (%)	Seed Yield of Mungbean (Mg ha <sup>-1</sup> )	Yield Reduction (%)	LER
T1	---	---	1.602	--	--
T2	5.96	---	---	--	--
T3	5.32	---	---	--	--
T4	4.62	---	---	--	--
T5	----	---	1.73	--	--
T6	5.84	---	---	--	--
T7	5.40	---	---	--	--
T8	5.03	---	---	--	--
T9	5.73	4.01	1.43	12.03	0.95
T10	5.51	3.45	1.49	7.52	1.01
T11	5.26	12.16	1.31	22.29	1.05
T12	5.82	11.68	1.52	13.82	0.97
T13	5.65	4.42	1.43	20.98	0.99
T14	5.33	5.62	1.24	39.52	0.971
Mean	<b>5.55</b>	<b>10.34</b>	<b>1.40</b>	<b>29.04</b>	<b>0.99</b>

Tropical lands such as the Philippines and Liberia usually have poor soil fertility, and continuous production may continually mine the soil of its nutrients. Intercropping of cereals and legumes may potentially improve the productivity of the land, and the use of inoculants such as Mykovam may enhance the symbiosis of the said cropping system. Mungbean, on the other hand, performed better under monocrop conditions with inoculation. Yield of mungbean with inoculation was 1.73 Mg ha<sup>-1</sup> whereas the monocrop non-inoculated had 1.60 Mg ha<sup>-1</sup>. However, the yield of mungbean intercropped with different maize varieties responded differently depending on the characteristics of the maize variety. Overall, though, mungbean reduced its yield under intercropping. Greatest yield reductions were under intercropping with UPLB Lagkitan with and without inoculation at 36.00% and 18.12%, respectively. This could be due to the tall stature of Lagkitan, which increased the shading of the mungbean, and as a response, the mungbean also grew taller in these treatments and had less photosynthates left for grain filling. Generally, maize+mungbean intercrop is advantageous over monocropping due to the synergistic effect of the crop combination that allows for better land resource and nutrient utilization, and allows diverse productivity per unit area. Inoculation helped both crop components obtain immobile nutrients in the soil, such as phosphorus. One must look out, however, that this inoculation would not exacerbate the problem of low soil fertility, should the soil microorganisms compete with resources such as carbon in the crop

components. It is also an important consideration to consider the variety of maize to use under an intercropping system in order to benefit from its use under such a cropping system.

## REFERENCES

1. Adeleye, B. N., Gershon, O., Oguno, A., Owolabi, O., Ogunrinola, I., & Adediran, O. (2020). Comparative investigation of the growth-poverty-inequality trilemma in Sub-Saharan Africa and Latin American and Caribbean Countries. *Heliyon*, 6(12).
2. Akchaya, K., Parasuraman, P., Pandian, K., Vijayakumar, S., Thirukumaran, K., Mustaffa, M. R. A. F., ... & Choudhary, A. K. (2025). Boosting resource use efficiency, soil fertility, food security, ecosystem services, and climate resilience with legume intercropping: a review. *Frontiers in Sustainable Food Systems*, 9, 1527256.
3. Amankwah, A., Ambel, A., Gourlay, S., Kilic, T., Markhof, Y., & Wollburg, P. (2024). Fertilizer price shocks in smallholder agriculture. *World Bank*.
4. Assefa, A., Abate, M., Haile, M., & Hunegnaw, Y. (2025). Land productivity and economic benefit of sorghum (*Sorghum bicolor* L.), mung bean (*Vigna radiata* L.) intercropping using intercrop indices and Partial budget analysis in Lasta District, North Eastern Ethiopia. *Discover Plants*, 2(1), 153.
5. Chen, Z., Wang, L., Cardoso, J. A., Zhu, S., Liu, G., Rao, I. M., & Lin, Y. (2023). Improving phosphorus acquisition efficiency through modification of root growth responses to phosphate starvation in legumes. *Frontiers in Plant Science*, 14, 1094157
6. Das, A., Das, D., & Richard, A. (2026). Socio-economic constraints to legume adoption among smallholders. *Journal of Food Legumes*, 39(Special issue), 205-213.
7. Dimkpa, C., Adzawla, W., Pandey, R., Atakora, W. K., Kouame, A. K., Jemo, M., & Bindraban, P. S. (2023). Fertilizers for food and nutrition security in sub-Saharan Africa: an overview of soil health implications. *Frontiers in Soil Science*, 3, 1123931.
8. Dimkpa, C., Adzawla, W., Pandey, R., Atakora, W. K., Kouame, A. K., Jemo, M., & Bindraban, P. S. (2023). Fertilizers for food and nutrition security in sub-Saharan Africa: an overview of soil health implications. *Frontiers in Soil Science*, 3, 1123931
9. Favero, V. O., Carvalho, R. H., Motta, V. M., Leite, A. B. C., Coelho, M. R. R., Xavier, G. R., ... & Urquiaga, S. (2021). Bradyrhizobium as the only rhizobial inhabitant of mung bean (*Vigna radiata*) nodules in tropical soils: a strategy based on microbiome for improving biological nitrogen fixation using bio-products. *Frontiers in Plant Science*, 11, 602645.
10. Gong, X., Ji, X., Long, A., Qi, H., & Jiang, Y. (2025). The effect of intercropping on phosphorus availability in plant–soil
11. Kumari, S., & Maiti, S. K. (2022). Nitrogen recovery in reclaimed mine soil under different amendment practices in tandem with legume and non-legume revegetation: A review. *Soil Use and Management*, 38(2), 1113-1145.
12. Lavelah, O. M., Edaño, M. L. S., Cruz, P. C. S., & Dizon, J. T. (2021). Growth, Yield, and Grain Quality of Three Maize Varieties and Mungbean under Different Cropping Systems Inoculated with Mykovam®. *International Journal of Research and Innovation in Social Science*, 5(4), 330-337.
13. Lesk, C., Anderson, W., Rigden, A., Coast, O., Jägermeyr, J., McDermid, S., ... & Konar, M. (2022). Compound heat and moisture extreme impacts on global crop yields under climate change. *Nature Reviews Earth & Environment*, 3(12), 872-889.
14. Maluki, M. (2023). Growth, nodulation and yield of selected legumes under drought conditions in Kitui county, Kenya (Doctoral dissertation).
15. MATHOBO, D. N. (2023). Sustainability of Vegetable Production Systems by Small-Scale Farmers of Limpopo Province in South Africa (Doctoral dissertation, University of the Free State).
16. Mekuria, M., Asfaw, D. S., & Tekalign, D. S. (2020). CLIMATE VARIABILITY IMPACTS AND DETERMINANTS ON CHOICE OF ADAPTATION STRATEGIES AMONG SMALLHOLDER FARMERS: THE CASE OF TOCHA WOREDA, DAWRO ZONE, SNNPR, ETHIOPIA (Doctoral dissertation, Haramaya university).
17. Mgwenya, L. (2025). Contextual analysis of government projects for food security in Kabokweni Ehlanzeni district, South Africa (Master's thesis).

18. Montero, J. M., Roberts, R. J., & Naimy, V. (2025). Revisiting zero hunger from a multidisciplinary perspective: How to measure hunger and reduce it?. *Equilibrium. Quarterly Journal of Economics and Economic Policy*, 20(1), 49-145.
19. Naik, S. K., Shinde, R., Mali, S. S., Sarkar, P. K., & Das, A. (2025). Land degradation: A global challenge to environmental sustainability and livelihood security. In *Ecological Solutions to Agricultural Land Degradation* (pp. 1-27). Singapore: Springer Nature Singapore.
20. Punongbayan, J. C. B. (2024). The Philippine Journal of Development in the Early 21st Century (2002–2023). *Philippine Journal of Development*, (2), 1-24.
21. Raza, A., Zahra, N., Hafeez, M. B., Ahmad, M., Iqbal, S., Shaukat, K., & Ahmad, G. (2020). Nitrogen fixation of legumes: Biology and Physiology. In *The plant family Fabaceae: biology and physiological responses to environmental stresses* (pp. 43-74). Singapore: Springer Singapore.
22. Scott, D., & Freckleton, R. P. (2022). Crop diversification and parasitic weed abundance: a global meta-analysis. *Scientific Reports*, 12(1), 19413.
23. Sonta, M., & Rekiel, A. (2020). Legumes are used for nutritional and feeding purposes. *Journal of elementology*, 25(3).
24. Takhumova, O. (2020, May). Rural development as a leading factor in economic growth. In *6th International Conference on Social, economic, and Academic Leadership (ICSEAL-6-2019)* (pp. 275-279). Atlantis Press.
25. Tamiru, W. (2022). Effect of intercropped forage legumes and their population with sorghum (*Sorghum bicolor* L.) on the performance and productivity of component crops in East Hararghe, Ethiopia (Doctoral dissertation, Haramaya University).
26. Tamiru, W. (2022). Effect of intercropped forage legumes and their population with sorghum (*Sorghum bicolor* L.) on the performance and productivity of component crops in East Hararghe, Ethiopia (Doctoral dissertation, Haramaya University).
27. Udvardi, M., Below, F. E., Castellano, M. J., Eagle, A. J., Giller, K. E., Ladha, J. K., ... & Peters, J. W. (2021). A research road map for responsible use of agricultural nitrogen. *Frontiers in Sustainable Food Systems*, 5, 660155.
28. Wang, Y., Zhang, R., Li, S., Guo, X., Li, Q., Hui, X., ... & Wang, H. (2024). An evaluation of potato fertilization and the potential of farmers to reduce the amount of fertilizer used based on yield and nutrient requirements. *Agronomy*, 14(3), 612.
29. Weih, M., Karley, A. J., Newton, A. C., Kiær, L. P., Scherber, C., Rubiales, D., ... & Tavoletti, S. (2021). Grain yield stability of cereal-legume intercroops is greater than sole crops in more productive conditions. *Agriculture*, 11(3), 255.
30. Wesseh, C. W. (2024). Food Security Challenges and Opportunities in Liberia: A Comprehensive Literature Review. Available at SSRN 5115934.
31. Yuliana, S., Nurul, H. B., Nani, H., & Rosah, A. A. (2021). Growth and Yield Of Maize (*Zea Mays* L.) Inoculated By Mycorrhizae And Intercropping With Mungbean In Dry Land. *Russian Journal of Agricultural and Socio-Economic Sciences*, 117(9), 176-184.