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FULL PAPER

Papaya-Mungbean Intercropping: Effect of Season and Different Row Spacing on the Growth and Yield Performance of Mungbean (*Vigna radiata* L.) Intercrop to Papaya (*Carica papaya* L.)

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The study was conducted to determine the productivity of papaya-mungbean intercropping as influenced by season and row spacing, while the cropping system was evaluated using multiple cropping index and partial budget analysis. Papaya was intercropped at wet and dry season with mungbean planted at different row spacing of 1.0 m, 0.75 m, and 0.50 m. Significant difference between the wet and dry seasons' effect in terms of plant height, pod length, number of pods per plant and total yield of mungbean intercropped to papaya was observed. However, when the three-row spacing was assessed individually, significant difference only on plant height and number of pods of mungbean intercropped to papaya was observed between the wet and dry seasons. However, significant difference on the growth and yield of mungbean intercropped to papaya was not detected using different row spacing regardless of season. The productivity of the intercropping was evaluated using Multiple Cropping Index (MCI), and partial budget analysis. The MCI value for wet and dry seasons was 169.44% indicating a 69% increase in land use. In terms of partial budget analysis, the row spacing that gave the highest income during wet season planting was 1.0 m, while during the dry season it was 0.5 m row spacing.

Keywords: crop diversification, intercropping, multiple cropping index (MCI), mungbean, partial budget analysis

INTRODUCTION

The Philippines has been known generally to be an agricultural country. The type of activity ranges from small subsistence farming and fishing to large commercial ventures with significant export focus. However, the agricultural land area of the country is only 10 M ha and, agriculture accounts only for 8.9% of Philippines' Gross Domestic Product as of 2022 (PSA 2023). With the decreasing area devoted to agriculture, the challenge for the agricultural sector is the sustainable production of large amount of food in a limited production area. This challenge can be addressed via crop diversification in the same piece of land. Crop diversification can be achieved by intercropping and multiple cropping systems (Hondrade et al. 2017). One strategy is the management of existing farms by increasing farm productivity using intercropping rather than exploiting other pieces of land. Farm productivity can be increased by diversifying crops planted in the same are in the farm.

Intercropping, a type of multiple cropping, is an intensive system of crop cultivation. Intercropping is the simultaneous cultivation of plant species in the same field for a considerable proportion of their growing periods. In intercropping system, two, three or more crops are planted simultaneously in the same field per year. On the other hand, multiple cropping includes mixed intercropping, row intercropping, strip intercropping, and relay intercropping. In sequential cropping, two or more crops are grown in sequence on the same field per year and include double cropping, triple cropping, quadruple cropping, and ratoon cropping (Gliessman 1985). An evidence showing that this kind of farming system has been existing dates back to as early as the ancient Chinese civilization. For example, rice double cropping system was widely adapted in China during the Ming Dynasty occurring between 1363 to 1644 (FAO 1980).

The interest in intercropping for sustainable agriculture is on the rise to maximize land use and farm (Tjeerdjan and Van der Werf 2020). According to Zaefarian and Rasvani (2016), the major benefit of intercropping is increasing the rate of crop production. Intercropping systems have been indicated to use resources differently and more efficiently, but more resources are used compared with monocropping system. The allelopathic interactions between the main crop and the intercrop are also of significance and must be considered in intercropping involving several economic crops (Zimdahl 2018; Cheng and Cheng, 2015). For instance, it is important to exploit cultivation systems that take advantage of the stimulatory/ inhibitory influence of allelopathic plants to regulate plant growth and development and to avoid allelopathic autotoxicity. Intercropping controls weeds by shading more significantly compared with monocropping. Intercropping also enhances the competitive ability of crops for nutrients and water compared to monocropping systems (Gebru 2015).

Legumes, such as mungbean (*Vigna radiata* L.), a short duration crop, have been used as an intercrop because they easily fit in cropping systems because of their short time window of three months from planting to harvest period. For example, mungbean was intercropped to cotton in Punjab, India (Khan et al.

2020) and custard apple in Africa (Kumar et al. 2014). Mungbean can be planted both during wet and dry seasons. In 2021, the area planted to mungbean in the Philippines was 41.7 thousand ha, while the yield was valued at PhP 2,273.9 M (PSA 2022).

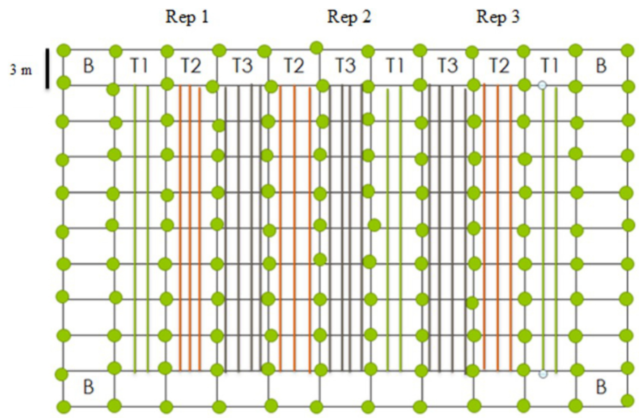
Papaya, one of the 10 leading fruit crops in the country has high nutritive value and has precocious flowering and harvesting of nine months after transplanting. During the period 2016 to 2020, papaya production has an average annual rate of 0.1%, from 162.48 thousand MT in 2016 to 163.30 MT in 2020 (PSA 2023). The crop is usually planted 2m x 3m or 3m x 3m apart. The distances between rows and plants in a row are wide enough to accommodate an intercrop to maximize land use. While this crop is generally susceptible to the papaya ringspot virus disease, new varieties tolerant to the virus are already available (Magdalita et al. 2021; Magdalita and Signabon 2017). There are several intercropping systems being used for papaya like papaya-pineapple, papaya-coffee-ginger, papaya-banana-pineapple, etc. In Cavite Province, intercropping papaya with either coffee, banana and pineapple is a very common practice in many farms (Philippine Recommends for Papaya Committee 2005). In Nigeria, papaya is being intercropped to vegetables like okra and cucumber including sunflower (Aiyelag and Jolaoso, 1992; Olubode et al. 2012, Anas et al. 2017). However, papaya-mungbean intercropping system is not commonly practiced in the Philippines, thus, needs to be investigated, hence this study. Identifying the most suitable row spacing of mungbean in an intercropping pattern with papaya will optimize the use of land area, improve fertility of the soil via nitrogen fixation by the mungbean in their nodules, increase farmers' income, and increase farm productivity on the overall.

The main objective of this study was to determine the productivity of papaya-mungbean an intercrop. Specifically, the study aimed to: i) determine the mungbean productivity intercropped to papaya during the wet and dry seasons, ii) determine the most suitable mungbean row spacing when intercropped to papaya and, iii) evaluate the productivity of the cropping pattern using multiple cropping index (MCI), and partial budget analysis.

MATERIALS AND METHODS

The intercropping and monocropping experiments separately were conducted on a 990 m^2 area with 30 m x 33 m dimensions at the UPLB Central Experiment Station in Tranca, Bay, Laguna (14°8'9.5928" N, 121°15'48.3516" E) from July 2016 to May 2017. Monocropping was also set up to serve as control. The area is flat with Batangas Clay Loam soil and bordered with different fruit trees and 'Saba' bananas in the northern and eastern sides.

The mungbean variety used was 'Pag-asa 19' which was planted as an intercrop to 'Sinta' papaya having 3m x 3m plant spacing. This intercropping system was conducted in two seasons namely: wet season and dry season. For the experiment on different row spacing of mungbean intercrop to papaya, three treatments with three replicates were used (Figure 1). The



- Green dot- one papaya hill;
- Thick colored lines represent the mungbean rows;
- Green lines indicate two mungbean rows in each replication;
- Orange lines indicate three mungbean rows in each replication;
- Gray lines indicate four mungbean rows in each replication.

Figure 1. The intercropping experimental layout of the field at the UPLB Central Experiment Station in Tranca, Bay, Laguna, Philippines.

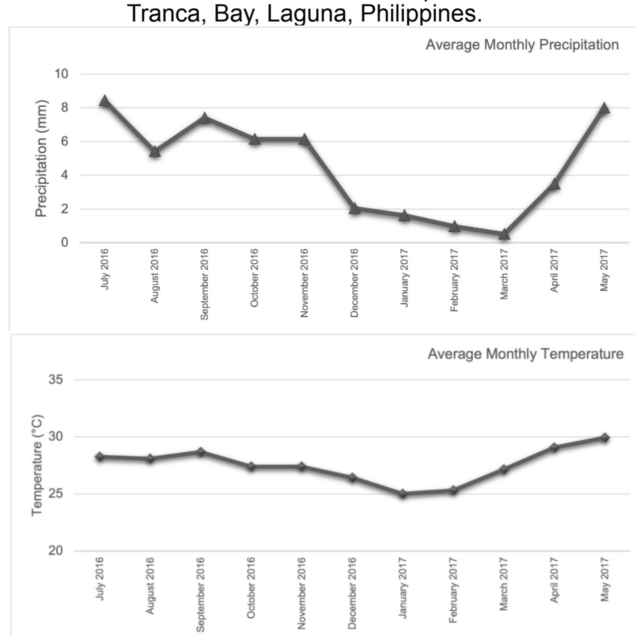


Figure 2. The monthly rainfall (mm) and temperature (°C) data from July 2016 to May 2017 in Los Baños, Laguna, Philippines.

(Source: Weather and Climate (2025). Los Baños Weather in July 2015 – May 2017. Historical Data for July 2015-May 2017 in Los Baños, Philippines. Weather and Climate. https://weatherandclimate.com/philippines/laguna/los-banos).

treatments were as follows: T1- 1.0 m mungbean row spacing or two mungbean rows between papaya rows; T2- 0.75 m mungbean row spacing or three mungbean rows between papaya rows; and T3- 0.50 m mungbean row spacing or four mungbean rows between papaya rows. Each treatment was planted in a 3 m × 24 m plot. The average temperature and rainfall in the area were also taken during the conduct of the experiment (Figure 2).

The papayas have been transplanted in each hill four months before the mungbean seeds were sown in the rows. The papaya seedlings were about 20cm high or one-month old before they were transplanted. Approximately 50g of the mixture of urea (45-0-0) and complete (14-14-14) fertilizer (3:1 v/v) were placed in each hole before transplanting and approximately 5g of a protectant fungicide (ai: 800 g kg^{-1} Mancozeb) was spread around the base of the newly transplanted papaya seedlings to prevent fungal diseases such as root rot and damping off.

The emerging weeds between the papaya rows were mowed. After clearing, the land was plowed, and furrows were made based on the experimental layout (Figure 1). Furrows with 1.0 m, 0.75 m, and 0.5 m spacing were mechanically constructed for each replicate. The mungbean seeds were sown thinly by hand in the furrows. Thinning was done to maintain 15–18 seedlings in each row for uniformity within treatments and across replicates. Fertilizer was applied as side-dress two weeks after sowing the mungbean seeds on the furrows. The climatic data during the conduct of the study from July 2016 to May 2017 is indicated in the graph that follows (Figure 2).

Statistical design and analysis

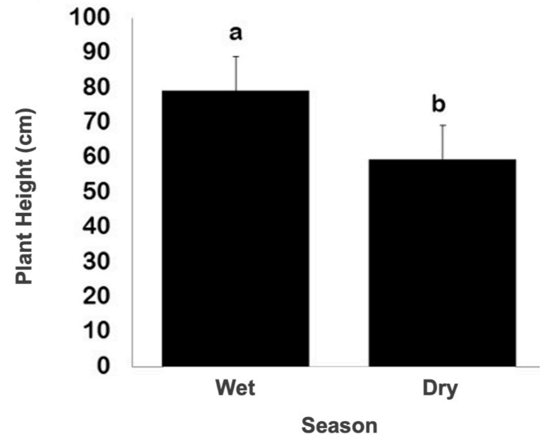
The Randomized Complete Block Design (RCBD) with three replications or blocks was used for the treatments regarding different row spacing of mungbean intercrop to papaya (Figure 1). The blocks were made perpendicular to the gradient of the field. The three row spacing treatments were randomized in each replication or block. The data collected were plant height (cm), yield (g) including 100-seed weight, number of seeds per pod, and number of pods per plant, and area planted (m^2) or total cropped area.

All data gathered were subjected to statistical analyses using One-way Analysis of Variance (ANOVA) using the Statistical Tool for Agricultural Research (STAR) (IRRI 2013). The significant difference between seasons was tested using the student t-test at 5% level of significance. On the other hand, the significant difference between treatment means was tested using the Least Significant Difference (LSD) with 5% level of significance.

The productivity of the intercropping system was evaluated using the MCI, a measure of intensive land use and high annual yield potential. Another measure of productivity of the cropping system is the partial budget analysis to assess the profitability of the intercropping system.

RESULTS AND DISCUSSION

In terms of the mungbean plant height, the plants grown during the wet season were significantly taller than those plants grown during the dry season (Figure 3). Significant difference for plant height between wet and dry seasons for the three treatments was also observed. During the wet season, the mungbean plants intercropped to papaya at 0.5, 0.75 and 1.0 row spacings are generally taller than those grown during the dry season (Figure 4). This result suggests that there is more inter-row competition for light during the wet season since light is limited due to cloudy and rainy days compared to the dry season, that is why the plants grew taller during the wet season. In addition, more water is provided to the plants during the wet season where precipitation is generally high (Figure 2).



Means with different letters are significantly different at α=5%.

Figure 3. Plant height (cm) of mungbean intercropped to papaya at dry and wet season.

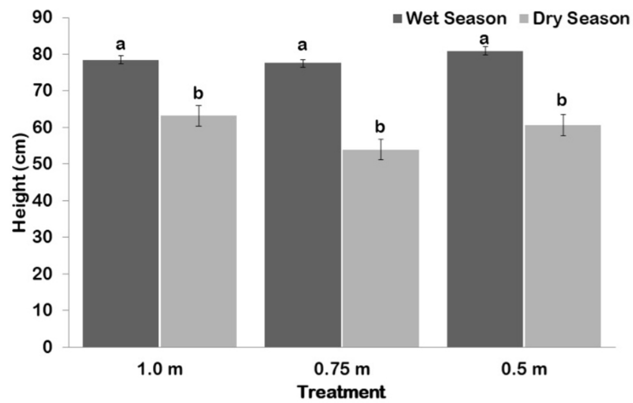


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Figure 4. Plant height (cm) of mungbean intercropped to papaya at different row spacing at dry and wet seasons.

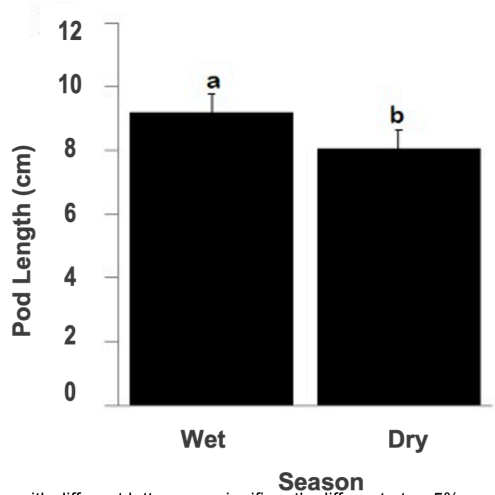

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Figure 5. Pod length (cm) of mungbean intercropped to papaya at dry and wet seasons.

This observation is similar to the previous report that during rainy season plants tend to grow taller, hence they need to be supported (https://www.americannativeplants.com/maintaining-garden-rainy-season). On the other hand, regardless of season,

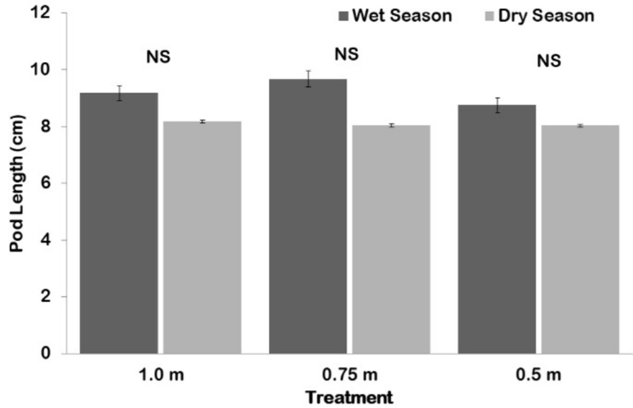

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Figure 6. Pod length of mungbean intercropped to papaya at different row spacing at dry and wet seasons.

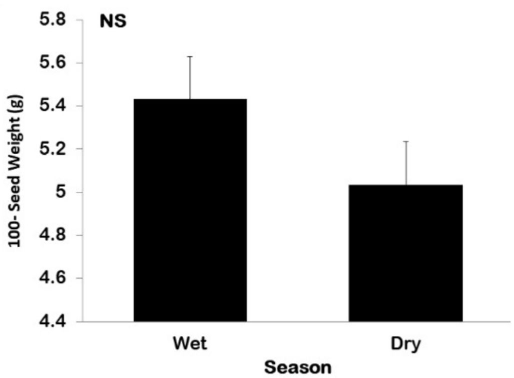

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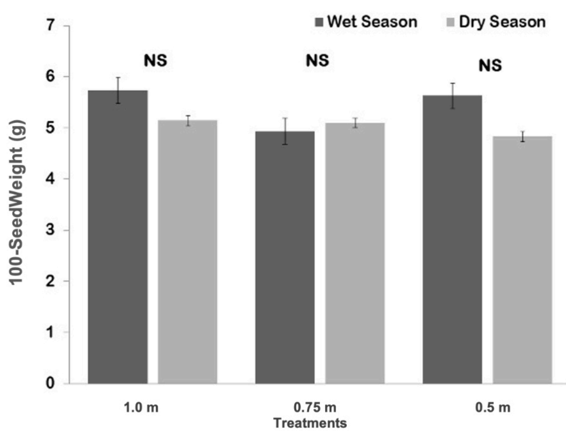
Figure 7. Hundred-seed weight of mungbean intercropped to papaya at wet and dry seasons.



Ns= Not significant

Figure 8. Hundred-seed weight of mungbean intercropped to papaya at different row spacing at dry and wet seasons.

Figure 9. Papaya-mungbean intercropping: Mungbean intercrop to papaya where the papaya main crop and the mungbean intercrop are both at the vegetative stage (A) and reproductive stage (B).

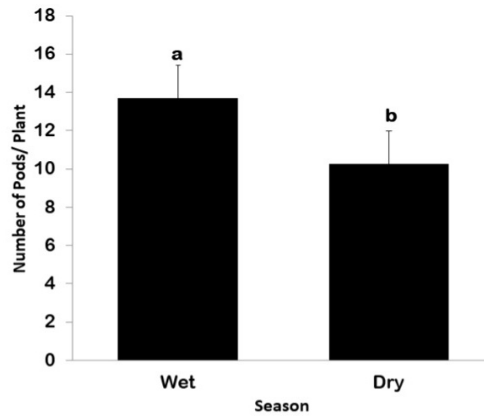


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Figure 10. Number of pods per plant of mungbean intercropped to papaya at wet and dry seasons.

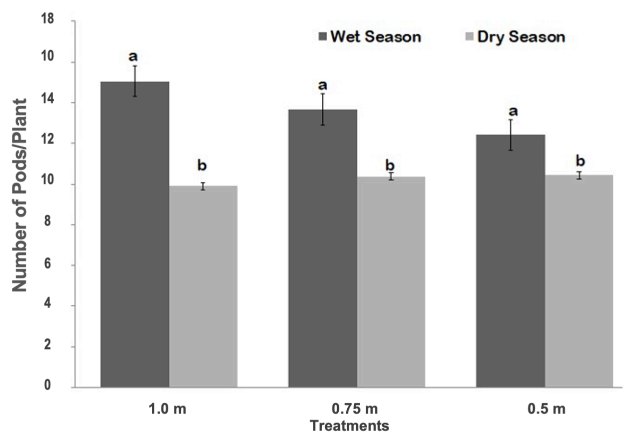

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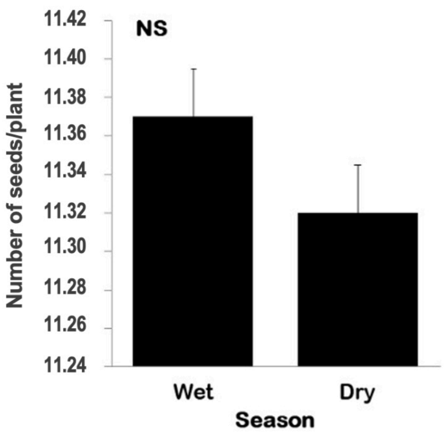
Figure 11. Number of pods per plant of mungbean intercropped to papaya at different row spacing at dry and wet seasons.

mungbean plants have similar plant height when intercropped to papaya at different row spacing of 0.5, 0.75 and 1.0 m (Table 1). This is probably due to the inherent genetic characteristic of the mungbean variety 'Pag-asa 19' that they are generally uniform in height. This suggests that uniformity in height was stably expressed by this mungbean variety, a characteristic that is expressed regardless of the cropping system where they are grown,

In terms of mungbean pod length, the pods of plants grown during the wet season were significantly longer than those pods of plants grown during the dry season (Figure 5). Plenty of water was obtained by the plants during the wet season due to high precipitation and minimum temperature required needed for plant growth (Figure 2). This observation corroborated with the previous report that in India, mungbean grown in the wet season has more pods per cluster that are

Table 1. Effect of row spacing on different yield parameters of mungbean intercropped to papaya.

Treatment	Plant height (cm)	Pod length (mm)	Number of pods/plant	Number of seeds/pod	100-seed weight	Total yield (g)
p-value	0.61^{ns}	0.99^{ns}	0.73^{ns}	0.69^{ns}	0.44^{ns}	0.80^{ns}
0.5 m row spacing	70.80 ± 11.46	44.54 ± 39.26	11.42 ± 1.55	11.42 ± 0.46	5.23 ± 0.54	4123.08 ± 1173.71
0.75 m row spacing	65.84 ± 13.03	45.02 ± 38.74	12.02 ± 1.94	11.24 ± 0.21	5.02 ± 0.64	3797.05 ± 1489.67
1 m row spacing	70.91 ± 9.90	45.49 ± 39.78	12.48 ± 3.10	11.38 ± 0.39	5.45 ± 0.52	3597.18 ± 1453.16



NS= Not significant;

Figure 12. Number of seeds per pod of mungbean intercropped to papaya at wet and dry seasons.

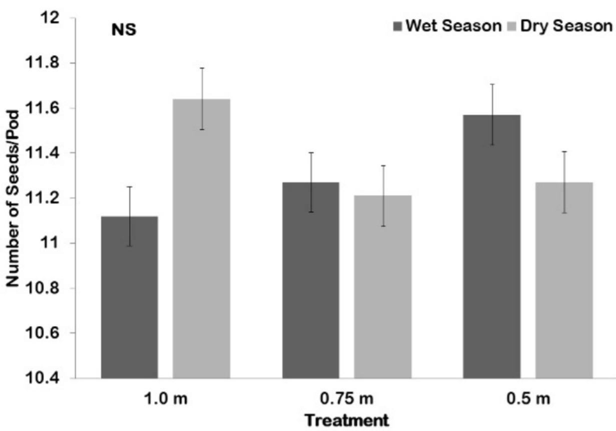


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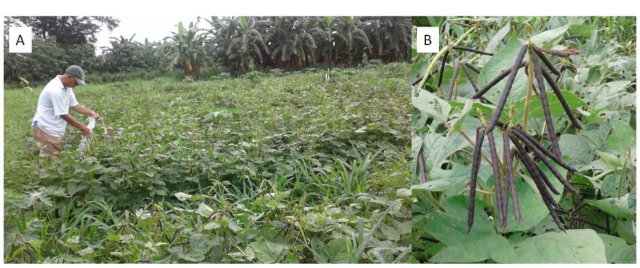
Figure 13. Number of seeds per pod of mungbean intercropped to papaya at different row spacing at wet and dry seasons.



NS= Not significant

Figure 14. Papaya-mungbean intercropping: First priming or harvesting (A) of physiologically mature mungbean pods (B).

longer, and more clusters developed per plant (https://www.sciencedirect.com). However, no significant difference for plant height between wet and dry

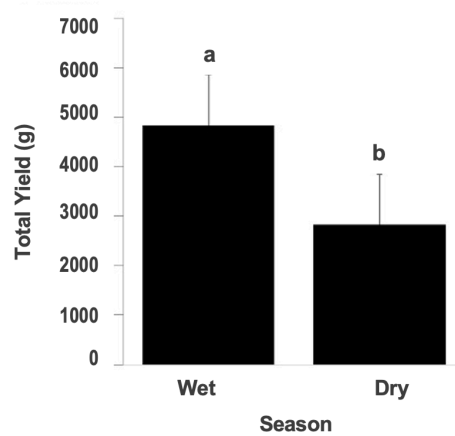


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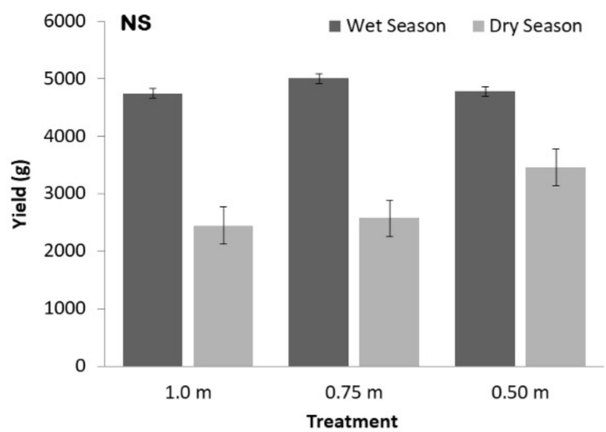
Figure 15. Total yield of mungbean intercropped to papaya at wet and dry seasons.



NS= Not significant

Figure 13. Total yield of mungbean intercropped to papaya at different row spacing at wet and dry seasons.

seasons for the three treatments was observed (Figure 6). Similarly, regardless of season, no significant difference on pod length was observed on mungbean plants intercropped to papaya at different row spacing of 0.5, 0.75 and 1.0 m (Table 1). This result suggests that this trait is also expressed stably by ‘Pag-asa 19’ regardless of season.

No significant difference was observed for 100-seed weight of mungbean plants intercropped to papaya during the wet and dry seasons (Figure 7). Also, no significant difference for 100-seed weight of mungbean plants was observed between wet and dry seasons for the three different treatments (Figure 8). Similarly, regardless of season, no significant difference on 100-seed weight was observed on mungbean plants intercropped to papaya at different row spacing of 0.5, 0.75 and 1.0 m (Table 1). This finding could be explained by the inherent uniform characteristics of the ‘Pag-asa 19’ mungbean seed weight, wherein this trait could be stable under different environmental conditions. This uniformity was also observed both during the vegetative and reproductive growth stages of mungbean in terms of plant height, vigor, canopy spread and gross growth characteristics (Figure 9).

The number of pods per plant is a key component in the production of legumes. Significant difference for number of pods per plant was observed between the wet and dry seasons (Figure 10). Significant difference for the number of pods produced between the wet and dry seasons for the three treatments was observed (Figure 11). During the wet season, significantly higher number of pods of mungbean intercropped to papaya at different row spacing of 0.5, 0,75 and 1.0 was observed compared to the dry season. This finding is similar to the previous report that during the rainy season in India, there is an increase in the number of bunches of mungbean per plant that would ultimately increase the number of pods per plant (https://www.sciencedirect.com). In addition, during the wet season, the soil moisture is highly available to mungbean during pollination and fertilization of flowers, hence more pods were formed. However, in tomato (*Lycopersicon esculentum*), anthers that produces pollen tend to dry up during the dry season, hence fruit production is highly affected (Villareal, personal communication). On the other hand, regardless of season, mungbean plants intercropped to papaya at different row spacing of 0.5, 0.75 and 1.0 m had no significant difference in terms of 100-seed weight (Table 1).

No significant difference was observed for the number of seeds per pod of mungbean plants intercropped to papaya during the wet and dry seasons (Figure 12). Also, no significant difference for the number of seeds per pod of mungbean plants was observed between wet and dry seasons for the three different treatments (Figure 13). Similarly, regardless of season, no significant difference on the number of seeds per pod was observed on mungbean plants intercropped to papaya at different row spacing of 0.5, 0.75 and 1.0 m (Table 1). The pods were harvested at the physiologically mature stage, *ie.* when they are black in color both during the first and second priming (Figure 14).

In terms of the total yield, which is a direct measure of productivity, significant difference between wet and dry season was observed (Figure 15). The mungbean plants grown during the wet season had significantly higher yield than those grown during the dry season, most probably due to the high amount of water provided by high precipitation during the wet season and minimum temperature for efficient photosynthesis of the plants (Figure 2). This finding is similar to the previous report of Kaysha et al. (2020) in Ethiopia that the three-way interaction effect of variety, fertilizer and row spacing influenced the above-ground biomass especially number of pods per plant and grain yield. However, no significant difference on the total yield of mungbean plants between wet and dry seasons for the three different treatments was observed (Figure 16). Similarly, regardless of season, no significant difference on the total yield of mungbean plants intercropped to papaya at different row spacing of 0.5, 0.75 and 1.0 m was observed (Table 1).

According to Beets (1982) and Peng et al. (2012), the potential productivity of a multiple cropping system and crop monitoring can be described by using the concept of the MCI. A high MCI means intensive land use and high annual yield potential. The MCI for papaya-mungbean intercropping at vegetative and reproductive stages of papaya yielded 169.44%, which denoted an increase in land use by 69%. A 169.44% MCI for the papaya-mungbean intercropping pattern indicates that in a year or less, the land was utilized more than once, suggesting a 100 percent land utilization high efficiency. Intercropping mungbean to papaya increased land use and this cropping system utilized fully the solar radiation which is an instantaneous resource. According to Khan et al. (2020), all intercropping systems like mungbean-cotton intercrop showed positive values of system productivity index and monetary advantage index.

The partial budget analysis was performed to determine the economic effect of intercropping mungbean to papaya. This was used as a tool for analyzing business changes such as intercropping in the farm (Ehui and Rey, 1992; Tigner, 2006). Partial budget computation for all treatments at vegetative stage and reproductive stage of papaya resulted in a positive number which indicated a beneficial change in the farming operation and an increase in farm income.

During the wet season papaya-mungbean intercropping, the treatment that had the highest positive value was treatment 1 with 1.0 m row spacing giving PhP 2,609.67, followed by 0.75 m row spacing with PhP 2,432.51, then the least was 0.5 m row spacing with PhP 1,628.04 only. The reason for this is that it had the lowest cost of production but more yield was obtained, thus lowering the negative effects. This indicates that intercropping mungbean to papaya at 1.0 m row spacing during the vegetative stage of the main crop which is papaya will give the highest increase in farm income during the wet season planting. On the other hand, during the dry season papaya-mungbean intercropping, the treatment that had the highest positive value was treatment 3 with 0.5 m row spacing giving PhP 5,8091.74, followed by 1.0 m row spacing with PhP 5,7928.97, then the least was 0.75 m row spacing with PhP 5,7603.01. This indicates that intercropping mungbean at 0.5 m row spacing to papaya at the reproductive stage of the main crop which is papaya will give the highest increase in farm income during the dry season planting. This result corroborated with the report of Anas et al. (2017) that intercropping of sunflower-mungbean and other intercrops gave more economic returns than sole cropping of sunflower and mungbean, and this system is superior with respect to grain yield and net economic return per unit area.

SUMMARY AND CONCLUSION

An intercropping experiment was conducted to assess the influence of season and three rows spacing of mungbean intercropped to papaya. To evaluate the farm productivity of papaya-mungbean intercropping, the multiple cropping index and partial budget analysis were used. The season of planting has significant effect on plant height, pod length, number of pods per plant and total yield of mungbean intercropped to papaya. However, the three-row spacing used for intercropping mungbean to papaya has no significant effect on growth and yield. A high multiple cropping index value of 169.44% was obtained during the wet and dry seasons planting. This indicates a 69% increase in land use in a papaya-mungbean intercropping within a year. Based on partial budget analysis of the intercropping system conducted, a row spacing of 1.0 m of mungbean plants intercropped to papaya gave the highest income during the wet season planting. On the other hand, a row spacing of 0.5 m provided the highest income during the dry season planting. In conclusion, intercropping of mungbean to papaya was affected by season, where the wet season generally promoted growth and yield. Based on multiple cropping index, papaya-mungbean intercropping maximizes land use efficiency and increases farm productivity.

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