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Agronomic Response of Upland Rice (Oryza sativa L.) var. Zambales to Mungbean (Vigna radiata L.) as Green Manure under Integrated Nutrient Management System

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ABSTRACT

The intensive application of inorganic fertilizer to crops is harmful to the environment. Green manuring and integrated nutrient management systems are ways to mitigate this problem sustainably. This study was conducted to evaluate the agronomic performance, determine the most suitable integrated nutrient management, and assess the profitability of growing upland rice with mungbean as green manure under an integrated nutrient management system. Results revealed that mungbean as green manure did not affect the agronomic characteristics, yield, and yield components of Zambales upland rice. Application of chicken manure at 2.5 t ha^{-1} + 45-30-30 kg ha^{-1} N, P_2O_5, K_2O delayed heading of Zambales upland rice while vermicompost at 2.5 t ha^{-1} + 45-30-30 kg ha^{-1} N, P_2O_5, K_2O delayed maturity. The yield and yield components of Zambales upland rice were not affected by integrated nutrient management. Green manuring using mungbean in Zambales upland rice production with different nutrient management systems was not profitable in Bato, Leyte during the wet season. Green manuring using mungbean of more than one cropping is recommended to further verify the results. Long-term application of chicken manure and vermicompost in combination with inorganic fertilizer is recommended for further study to investigate its effect on the soil properties, growth, and yield of upland rice.

Keywords: green manure, nutrient management, organic fertilizer, upland rice

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops and staple food for nearly half of the world's population (Prasad et al 2017). More than 90% of rice is consumed in Asia where it is a staple for a majority of the population (International Rice Research Institute [IRRI] 2013). To become self-sufficient in rice, upland rice farming may help. However, the yield of upland rice is generally lower than lowland rice. GRiSP (2013) stated that the country's average rice yields in the lowlands are about 2.3 t ha^{-1} and 1 t ha^{-1} in the uplands. The resulting rice yield is low due to

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further constraints arising from the widespread incidence of problem soils with poor physical and chemical properties. To address this problem, organic matter in the soil must be maintained and/or increased.

One of the important indicators of productive soil is soil organic matter (SOM) which plays an important role in maintaining the sustainability of cropping systems by improving the physical, chemical, and biological properties of the soil (Fageria 2012). The preservation of soil organic matter is crucial to ensure the long-term sustainability of agricultural ecosystems which can be achieved by adopting soil and crop management practices such as the use of green manures (Fageria 2012) and organic manures (Khan et al 2004). Green manure crops include grain legumes such as mungbean.

Mungbean is an early maturing grain legume crop that is commonly found and planted in the Philippines. Most green manure nitrogen mineralizes within four weeks of incorporation, potentially limiting nitrogen availability after rice panicle initiation (Meelu & Morris 1988). To resolve this problem, the application and addition of another source of fertilizers such as inorganic and organic fertilizers or both may be helpful in order to meet the nutrients needed by rice throughout the growing period. Integrated nutrient management system refers to the practice of using both inorganic and organic fertilizers to improve crop productivity while protecting the environment is the best strategy in solving the aforesaid constraint.

The major concern today is to meet the food demand of the growing population by maintaining good soil health at a lower cost of production without hampering the quality of the environment. Green manuring and organic fertilizer application present themselves as potential methods for meeting this need (Rosegrant & Roumasset 1988). However, limited information is available, especially on the use of green manure under an integrated nutrient management system for upland rice. Thus, this study was conducted to evaluate the growth and yield of upland rice with mungbean as green manure under integrated nutrient management system, and determine the most suitable integrated nutrient management for upland rice with mungbean as green manure.

METHODOLOGY

Time and Place of the Study

This study was conducted from August 8, 2020 to February 03, 2021 at the farmer's field in Barangay Naga, Bato, Leyte, Philippines. The barangay is situated in the upland area.

Land Preparation

For the main plot 1 (M_1, with green manure), plowing was done once and furrows were made after at a distance of 0.5 m between rows. In mainplot 2 (without green manure), the land was left unsown and uncultivated throughout the growing period of mungbean under mainplot 1.

At the flowering stage, mungbean was incorporated into the soil by plowing the soil using a carabao-drawn implement. Two weeks later, an area of 667 m2 was plowed and harrowed twice using animal drawn implement at weekly intervals in order to pulverize the soil, level the field, and remove the weeds. After the last harrowing, furrows were constructed at a distance of 0.5 m.

Soil Sampling and Analysis

Ten soil samples were collected randomly in the entire field area from the surface up to 20 cm depth using soil auger before sowing mungbean. The collected soil samples were thoroughly mixed, composited, air-dried, pulverized, and sieved using 2 mm and 0.5 mm wire mesh. The composite sample was submitted and analyzed at the Central Analytical Service Laboratory (CASL) for soil pH (potentiometric method at 1:2.5 soil: water ratio (ASTM, 1995), % organic matter (Modified Walkley Black method) (Walkley & Black, 1934), total nitrogen (Kjeldal Method) (ISRIC 1995), available P (Bray 2) (Bray and Kurtz, 1945), and exchangeable K (ammonium acetate method pH 7.0 for extraction and quantified using Varian 220 FS Atomic Absorption Spectrometer) (Edmeades and Clinton,1981). After harvest, soil samples were collected from each treatment per plot. These were composited processed and analyzed for the same soil parameters using the same methods mentioned above

Experimental Design and Treatment Levels

The experiment was laid out in a split plot in a Randomized Complete Block Design (RCBD) with three replications. A total of thirty-six plots were prepared for the entire experiment. To facilitate data gathering and farm operations, each replication and subplot were separated by an alleyway measuring 1 m. The treatments were designated as follows:

Main plot: (Green Manure Application)
- M_1 = with Green Manure
- M_2 = without Green Manure

Subplot: (Integrated Nutrient Management Systems)
- T_0 = No fertilizer application (Control)
- T_1 = Chicken Manure at 5 t ha^{-1}
- T_2 = Vermicompost at 5 t ha^{-1}
- T_3 = Chicken Manure at 2.5 t ha^{-1} + 45-30-30 kg ha^{-1} N, P_2O_5, K_2O
- T_4 = Vermicompost at 2.5 t ha^{-1} + 45-30-30 kg ha^{-1} N, P_2O_5, K_2O
- T_5 = 90-60-60 kg ha^{-1} N, P_2O_5, K_2O (RR)

Planting of Mungbean and Upland Rice

Mungbean (*Vigna radiata* L. variety Pag-asa 19) was selected as a pre-rice legume due to the availability of seeds and wide adoption. Sowing of mungbean was done after furrowing. Mungbean seeds were evenly drilled along furrows and covered by a thin layer of soil. To achieve the 15 plants per linear meter, thinning was 10 days after sowing to attain the desired population of 300,000 plants per hectare and left to grow until the flowering stage.

Seeds of the Zambales variety were drilled in furrows (12 g/row) at the seeding rate of 80 kg ha^{-1} and were covered with a 3-5 cm layer of soil to protect them from dehydration, birds, and ants.

Fertilizer and Fertilizer Application

During the fallow period, mungbean in M_1 was applied with complete fertilizer at the rate of 30-30-30 kg ha^{-1} N, P_2O_5, K_2O. Basal application of complete fertilizer amounting to 257.14 grams $plot^{-1}$ was applied before sowing the seeds.

For the organic fertilizers, chicken manure, and vermicompost were applied following the rate specified in the treatment. The organic fertilizers were distributed and incorporated manually one week before sowing the seeds of upland rice. Complete fertilizer and urea were the inorganic fertilizers used in the study.

At sowing, basal application of complete fertilizer was done at the rate of 30-30-30 kg ha^{-1} N, P_2O_5, K_2O for T_3 and T_4 while 60-60-60 kg ha^{-1} N, P_2O_5, K_2O for T_5. This was followed by side dressing urea at the rate of 15 kg ha^{-1} N for T_3 and T_4, while 30 kg ha^{-1} N for T_5 at panicle initiation.

Control of Weeds, Insects and Diseases

At three weeks after emergence, manual weeding was done. The second weeding was done right after hilling-up at two weeks after the first weeding to control weeds at the base of the crop as well as to provide better anchorage of the plants.

Rice plants were sprayed with 25 g of Lannate insecticide mixed with 16 liters of water at the flowering and at the milking stage to control rice bugs. During the milking stage until maturity, the field was guarded at sunrise until sunset or dusk to drive away chicken (*Gallus gallus domesticus*) which attacked the rice grains.

Harvesting

Harvesting was done when approximately 85% of the rice grains in each plot had ripened as indicated by its yellow color and firm grains. All the sample plants within the harvestable area in 4 inner rows, excluding the 4 borders and 0.50 m end plants in each row (4 m^2) were harvested using a sharp sickle. The panicles were cut near the base, threshed, sun-dried for 2-3 days or to about 14% moisture content, and winnowed before gathering all the required data.

Data Gathered

Total weekly rainfall (mm), minimum and maximum temperatures (^0C), and relative humidity (%) throughout the conduct of the study were taken from the record of the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) Station, Capitol Site, 6600 Maasin City, Southern, Leyte.

The number of days from sowing to heading and maturity was determined by counting the number of days from sowing up to the time when 50% of the panicles from each treatment plot had exerted from the flag leaf sheath and up to the time when 85% of the panicles in each plot had reached maturity as indicated by the firm and yellowish color of the grains, respectively. The plant height (cm) was determined by measuring ten sample hills in each plot from ground level up to the tip of the tallest part of the plant at maturity.

The leaf area index was determined at the heading by measuring the length and width (broadest part) of all functional leaves of plants inside the 0.20 linear meter. The total leaf area was computed by multiplying the length and the width of every leaf. The leaf area index was computed using the equation.

$$LAI = \frac{Total\ Leaf\ Area = \sum L \times W \times CF\ (0.75)}{Ground\ area\ in\ 0.20\ linear\ meter\ per\ plot\ (1{,}000\ cm^2)}$$

The number of productive tillers hill^{-1} at maturity was determined by counting the number of tillers per linear meter that produced panicles in each plot. The number and weight of filled and unfilled grains in panicle^{-1} were determined by counting and weighing the number of filled and unfilled grains of ten sample panicles in each plot. The weight of 1,000 grains was determined by weighing 1,000 grains randomly obtained in each plot.

The percentage-filled spikelet panicle^{-1} was quantified by using the formula:

$$\%\ filled\ grains\ panicle^{-1} = \frac{number\ of\ filled\ grains}{number\ of\ filled + unfilled\ grains} \times 100$$

The grain yield (t ha^{-1}) was determined by weighing the grains harvested from the harvestable area of each treatment plot. The grains from panicles of each treatment plot were harvested and threshed. The grains were sundried at approximately 14% MC and cleaned before weighing. The weight per plot was converted into tons per hectare using the formula:

$$Grain\ yield\ (t\ ha^{-1}) = \frac{Plot\ yield\ (kg)}{Harvestable\ area\ (4\ m^2)} \times \frac{10000\ m^2 ha^{-1}}{1000\ (kg\ ton^{-1})}$$

Statistical Analysis

ANOVA of gathered data was done using Statistix 8.1. Mean comparison was done using the Honestly Significant Difference (HSD) or Tukey's test.

RESULTS AND DISCUSSION

Meteorological Conditions in the Experimental Site

The weekly rainfall ranged from 21 mm - 209.20 mm, relative humidity from 78.85% -90.28 %, and minimum and maximum temperature ranged from 23.37-24.81 °C and 27-31.88 °C, respectively with a total amount of rainfall of 1519.20 mm (Fig. 1). According to De Datta (1981), the rainfall requirement for upland rice is preferably 100 to 200 mm month^{-1}. In other words, the weekly rainfall requirements for upland rice range from 22.99 mm to 45.98 mm.

In this study, meteorological data showed that the average weekly rainfall from nine weeks after planting to harvesting was 84.40 mm. The average weekly rainfall during the conduct of the experiment exceeds the rainfall requirement of upland rice. Thus, the amount of precipitation recorded was too much for upland rice. The average minimum and maximum temperatures throughout the growth of upland rice were 23.99 ^{0}C and 29.37 ^{0}C, respectively. Yin et al (1996) reported that the optimum temperature requirements for normal growth and development of rice ranged from 27^{0}C to 32^{0}C. Thus, the recorded temperature values were within the range for optimum requirement for the normal growth and development of rice. Similarly, the average relative humidity (86.13%) recorded throughout the growing period of rice was closely associated to the range for rice cultivation which ranges from 60% - 85% (Rathnayake et al 2016).

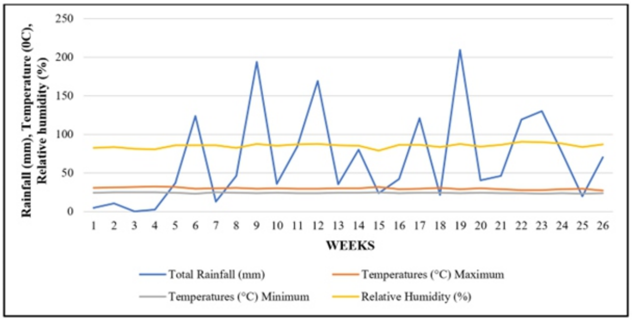

Figure 1. Total weekly rainfall (mm), minimum and maximum temperatures (^{0}C), and relative humidity (%) throughout the duration of the study (August 08, 2020 to February 03, 2021) obtained from the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) Station, Capitol Site, 6600 Maasin City, Southern, Leyte

Soil Conditions in the Experimental Site

The soil in the experimental area was strongly alkaline, with very low amount of organic matter, very low total N, high in available phosphorus and with medium amount of exchangeable K (Table 1).

After harvest, a slight increase was noted in pH, organic matter and exchangeable K (me 100 g^{-1}) in soil under green manure (M_1) and without green manure (M_2) relative to the initial analysis. A remarkable increase in available P (mg kg^{-1}) was observed in with or without green manure relative to initial analysis. The same mean value of N (0.09%) was recorded in M_1 (with green manure) and M_2 (without green manure). The result implies that green manuring did not increase the N content of the soil. The reason could be due to N-rich leguminous green manures which decompose rapidly and release nutrients quickly and taken up by the plants (Roy et al 2006).

Table 1. Initial and final analysis of soil planted to upland rice as influenced by green manure under an integrated nutrient management system

TREATMENTS	SOIL PH (1:2.5)	OM %	TOTA L N %	AVAILABLE P (MG KG^{-1})	EXCHANGEABL E K (ME 100G^{-1})
Initial Soil Analysis	7.82	1.07	0.09	22.16	0.25
Final Soil Analysis					
Green Manure					
M_1 - With Green Manure	8.19	1.16	0.09	46.43	0.34
M_2 - Without Green Manure	8.34	1.16	0.09	45.65	0.32
Mean	8.27	1.16	0.09	46.04	0.33
INM System					
T_0 - No fertilizer application (Control)	8.33	1.12	0.10	27.28	0.29
T_1 - Chicken Manure at 5 t ha^{-1}	8.31	1.19	0.09	83.48	0.39
T_2 - Vermicompost at 5 t ha^{-1}	8.32	1.17	0.09	35.64	0.29
T_3 - Chicken Manure at 2.5 t ha^{-1} + 45-30-30 kg ha^{-1} N, P_2O_5, K_2O	8.29	1.22	0.09	54.64	0.33
T_4 - Vermicompost at 2.5 t ha^{-1} + 45-30-30 kg ha^{-1} N, P_2O_5, K_2O	8.08	1.13	0.10	39.20	0.36
T_5 - 90-60-60 kg ha^{-1} N, P_2O_5, K_2O (RR)	8.30	1.12	0.09	35.98	0.33
Mean	8.27	1.16	0.09	46.04	0.33

Number of Days from Sowing to Heading and Maturity

Upland rice applied with chicken manure at 2.5 t ha^{-1} + 45-30-30 kg ha^{-1} kg N, P_2O_5, K_2O headed later compared to those that did not receive fertilizer (control) but was comparable to those plants applied with vermicompost at 2.5 t ha^{-1} + 45-30-30 kg ha^{-1} N, P_2O_5, K_2O and to those plants applied with the recommended rate of inorganic fertilizer (Figure 2). Consequently, plants applied with vermicompost at 2.5 t ha^{-1} + inorganic fertilizer at 45-30-30 kg ha^{-1} (integrated nutrient management) matured later. Plants with insufficient nutrients would senesce earlier than plants with sufficient nutrients thus, control plants headed and matured earlier. Nitrogen nutritional limitation has been found to increase leaf senescence (Bieker & Zentgraf 2013).

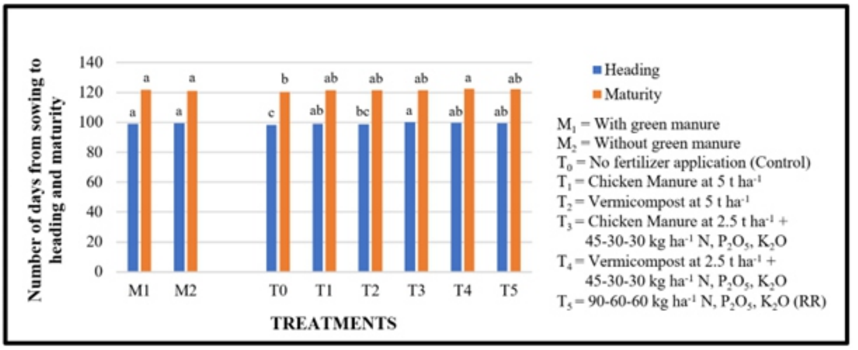

Figure 2. Number of days from sowing to heading and maturity of upland rice as influenced by green manure under an integrated nutrient management system

Plant Height at Maturity

Upland rice applied with full inorganic fertilizer at the rate of 90-60-60 kg N, P_2O_5, K_2O kg ha^{-1} (T_5) were significantly taller than the unfertilized plants. However, plants under integrated nutrient management systems (T_3 and T_4) and those applied with chicken manure (T_1) and vermicompost (T_2) alone did not differ significantly (Fig. 3).

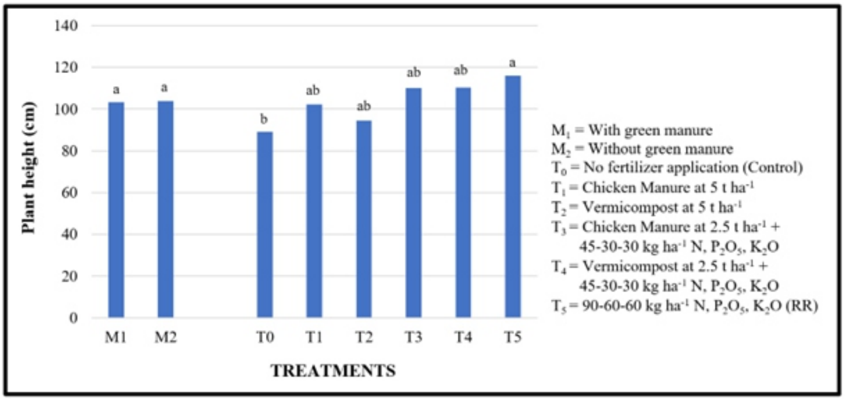

Figure 3. Plant height (cm) of upland rice of upland rice as influenced by green manure under an integrated nutrient management system

Leaf Area Index

Upland rice that received the full dose of inorganic fertilizer gave significantly higher LAI than the control plants and those plants that received the vermicompost alone (Fig. 4). The LAI of those plants applied with combined organic fertilizer and inorganic fertilizer were comparable to those applied with inorganic at the full dose of the recommended rate. The results corroborate the findings of Baoy and Bañoc (2017) who reported that application of full dose inorganic fertilizer (120-60-60 kg N, P_2O_5, K_2O kg ha^{-1}) on lowland rice resulted in taller plants and larger LAI that could be due to the readily available supply of macro-nutrients needed by crops for their growth and development.

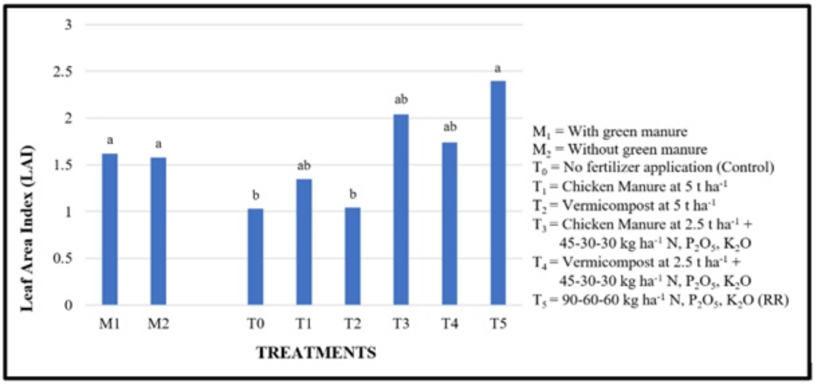

Figure 4. Leaf area index of upland rice as influenced by green manure under an integrated nutrient management system

Yield and Yield Components

Table 2 shows the yield and yield components of upland rice as influenced by green manure under an integrated nutrient management system. Results revealed that the yield components studied as well as the grain yield of upland rice were not significantly affected by the application of green manure and integrated nutrient management system. Likewise, no interaction was observed between green manuring and integrated nutrient management adopted. The result conformed to the study of Capuno et al (1980) who reported that the application of green manure did not increase grain yield of sorghum. This implies that green manuring at one cropping did not affect the yield of upland rice directly. Long-term use of legume crops as green manure might be needed to improve the soil health and consequently, increase the yield of upland rice. Likewise, the application of organic fertilizer alone or in combination with inorganic (integrated nutrient management system) did not contribute to the increase in yield. In the study of Castillo et al (2012), it was reported that plots applied with chicken manure and no fertilizer gave comparable grain yields, showing that the one season application of chicken manure does not contribute to the increase in rice grain yield. On the other hand, after 6 continuous cropping seasons (3 wet and 3 dry), chicken manure had a higher average yield than the unfertilized plants (Javier et al 2002).

Table 2. Yield and yield components of upland rice as influenced by green manure under an integrated nutrient management system

TREATMENT	Number of productive tillers (linear $meter^{-1}$)	Number of filled grains $panicle^{-1}$	Number of unfilled grains $panicle^{-1}$	Weight(g) of filled grains $panicle^{-1}$	Weight(g) of unfilled grains $panicle^{-1}$	Percent filled grains $panicle^{-1}$	Weight (g) of 1,000 grains	Grain yield (t ha^{-1})
Green manure								
M_1 - With green manure	57.94[a]	94.73[a]	24.30[a]	2.84[a]	0.21[a]	79.40[a]	29.67[a]	1.48[a]
M_2 - Without green manure	55.78[a]	90.78[a]	21.08[a]	2.82[a]	0.20[a]	80.75[a]	29.88[a]	1.45[a]
Mean	56.86	92.76	22.69	2.83	0.21	80.08	29.77	1.46
INM System								
T_0 - No fertilizer application (Control)	46.00[a]	82.77[a]	19.53[a]	2.31[a]	0.18[a]	80.61[a]	29.55[a]	1.23[a]
T_1 - Chicken Manure at 5 t ha^{-1}	52.33[a]	95.63[a]	18.40[a]	2.66[a]	0.19[a]	83.20[a]	29.65[a]	1.36[a]
T_2 - Vermicompost at 5 t ha^{-1}	56.83[a]	75.83[a]	17.20[a]	2.15[a]	0.15[a]	80.52[a]	28.33[a]	1.38[a]
T_3 - Chicken Manure at 2.5 t ha^{-1} + 45-30-30 kg ha^{-1} N, P_2O_5, K_2O	67.83[a]	92.10[a]	23.63[a]	2.94[a]	0.21[a]	79.51[a]	30.40[a]	1.47[a]
T_4 - Vermicompost at 2.5 t ha^{-1} + 45-30-30 kg ha^{-1} N, P_2O_5, K_2O	57.33[a]	105.48[a]	28.17[a]	3.54a	0.25[a]	78.30[a]	30.92[a]	1.68[a]
T_5 - 90-60-60 kg ha^{-1} N, P_2O_5, K_2O (RR)	60.83[a]	104.73[a]	29.20[a]	3.40[a]	0.24[a]	78.30[a]	29.78[a]	1.66[a]
Mean	56.86	92.76	23.19	2.83	0.20	80.07	29.77	1.46
(GM x IS)	ns	ns	ns	ns	ns	ns	ns	ns
C.V. (a) %	6.34	15.20	10.66	15.18	28.54	2.77	5.93	14.29
C.V. (b)%	19.65	25.76	31.25	27.15	32.74	7.61	5.18	17.75

Means within a column with the same letter(s) are not significantly different at 5% level, HSD.

The results of this experiment showed that the yield of upland rice was lower compared to the reported average yield of 1.5 tons ha^{-1}. This might be due to the unfavorable conditions during the growing season of the crop. The amount of rainfall was one of the factors which affected the yield of upland rice. The total amount of rainfall exceeds the optimum amount required by the crop for its normal growth and development. De Datta and Vergara (1975) explained that moisture stress is damaging and can kill plants in an area that receives as much as 200 mm of precipitation in one day, and then receives no rainfall the next 20 days.

De Datta and Vergara (1975) reported that the yield of upland rice in the Philippines is closely associated with climatic zones and rainfall patterns having an average yield of 0.66 t ha^{-1} only in the low rainfall areas where rainfall is sufficiently distributed with a maximum period of 4% dry months. Conversely, in high rainfall areas where rainfall is evenly distributed throughout the season, but with 3 dry months, the average yields reached 1.1 t ha^{-1}. De Datta et al (1974b) as cited by De Datta and Vergara (1975) stated that the national average of upland rice in the Philippines is about 0.9 t ha^{-1}. On the other hand, the average yield of upland rice increased to 1.5 t ha^{-1} in 1997 (Sebastian et al 2000).

CONCLUSION

Based on the results obtained, using mungbean as green manure did not affect the agronomic characteristics, yield, and yield components of Zambales upland rice. Application of chicken manure at 2.5 t ha^{-1} + inorganic fertilizer at 45-30-30 kg ha^{-1} N, P_2O_5, K_2O delayed heading of Zambales upland rice while the application of vermicompost at 2.5 t ha^{-1} + inorganic fertilizer at 45-30-30 kg ha^{-1} N, P_2O_5, K_2O delayed maturity. The yield and yield components of Zambales upland rice were not affected by integrated nutrient management.

RECOMMENDATION

Since the study was conducted for one cropping season, it is recommended to conduct a similar study of more than one cropping to further verify the results. Long-term and continuous application of chicken manure and vermicompost as sources of organic fertilizer in combination with inorganic fertilizer is recommended for further study to investigate its effect on the soil properties, growth, and yield of Zambales upland rice.

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