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Comparative Performance of Selected Soil Inoculant, Soil Amendment, and Foliar Fertilizer in Enhancing Upland Rice Production

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ABSTRACT

The rising cost of farm inputs (fertilizers) results in higher production expenses in rice farming; thus, meeting the country's growing demand for food is at stake due to a lack of capital for production. The agriculture department pinned several strategies to boost rice production through new varieties and mechanization to secure food sufficiency. Contributing to boosting rice production was why this study was encapsulated, and evaluating the efficacy of selected soil inoculants, soil conditioners, and organic foliar fertilizers on agronomic yield and yield components of rice (NSIC Rc 27) was the objective. A completely randomized block design was used in the study (RCBD) with eight (8) treatments: T_1 = Farmers Practice (FP), T_2 = Recommended Rate of Fertilizers (RRF) Application, T_3 = Soil Inoculant Application (SIA), T_4 =Foliar Fertilizer Application (Carrageenan) (FFA), T_5 = Soil Amendments Application (SAA) combined with soil Inoculants (CRH and *Bacillus amyloliquefaciens*), T_6 = Foliar Fertilizer combined with soil inoculant, T_7 = 50% RRF combines with Foliar Fertilizer and soil inoculant and T8 = 50% RRF combines with soil inoculant and replicated thrice in a 4m x 5m standard size with a total area of 646m^2 with the duration of two years. The research was conducted at Davao de Oro State College's research laboratory at Compostela, Davao de Oro. Agronomic parameters, meteorological data, yield and yield components, and economic analysis were collected. The results confirmed that various approaches increased upland rice production by up to 3.9 tons per hectare. On the other hand, soil conditioners and soil inoculants like carbonized rice hull (CRH) and *Bacillus spp* could improve soil health by increasing organic matter, resulting in better absorption of nutrients correlating to higher production.

INTRODUCTION

Rice (*Oryza sativa* L) is widely cultivated due to its wide range of soil types and climate adaptation. One of the world's top rice producers is located in Southeast Asia. China, Vietnam, Thailand, Cambodia, and the Philippines are rice-producing countries, according to IRRI (2000). It is a staple food for tropical countries like the Philippines, and 90% of the population is a rice consumer because it is rich in carbohydrates and protein and is a significant energy source.

Philippine Statistics Authority (PSA, 2022) reported a substantial 26.50% decrease in the rice inventory, which amounted to 1.84 million metric tons compared to the same period in the previous year. This decline signified a reduced availability of rice in the country. Meanwhile, the municipality of Compostela, known as the rice granary of Davao de Oro and ranking as the second top rice producer in the Davao region, experienced an average growth rate of -4.30% from 2018 to 2020, as reported by the PSA in 2021. This significant yield decrease has reduced income for local rice farmers. Various factors have contributed to the decline in rice production in the Davao region, including high input costs, the effects of climate change, issues related to pests and diseases, mismanagement of nutrients, and socioeconomic factors, among others. These challenges, coupled with the increasing demand for high-quality rice, have led to the importation of 133,500 MMT of rice grains annually to address the growing demand of the Filipino population.

A shift towards sustainable practices is imperative to address the challenges above in rice production. One potential solution mitigating high input costs lies in utilizing soil inoculants, foliar fertilizers, and soil amendments, which have advantages in rice farming. It plays a pivotal role in nutrient cycling, making essential elements like phosphorus more accessible to rice plants, thereby fostering their growth. Moreover, its ability to utilize various carbon sources and thrive across a broad temperature range (3 °C to 45 °C) positions it as an ideal candidate for enhancing agricultural processes (De Vos P. *et al.,* 2009).

Compared to traditional synthetic farming, this approach offers an alternative to soil. By reducing the reliance on synthetic chemicals, this innovative approach mitigates the negative environmental impacts and enhances the overall resilience of rice crops to pests and diseases. This, in turn, fosters food security and contributes to economic stability, benefiting both farmers and consumers.

In pursuit of sustainable rice production, using soil inoculants, soil amendments, and foliar fertilizers holds promise. It aims to produce fewer synthetic rice grains and much more nutritious ones, potentially reducing its dependence on synthetic fertilizers and enhancing overall crop productivity. Thus, the primary objective of this research study is to enhance upland rice production using soil inoculant, soil conditioner, and foliar fertilizer and

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evaluate their effects on agronomic and yield through a soil-based approach.

Specifically, this research study aims to:

a. Investigate the effects of selected soil inoculants, soil conditioners, and foliar fertilizers on the growth and yield of upland rice and

b. Assess the fertility status of the soil and determine its suitability for upland rice production using selected soil inoculants, soil conditioners, and foliar fertilizers on the growth and yield of upland rice.

MATERIALS AND METHODS

Study Location and Duration

The study was conducted in Davao de Oro State College Agriculture Field Laboratory Maparat, Compostela, Davao de Oro, approximately 7.6863N, 126.0468E, under the category IV climate type and has an elevation of 90 – 93 meters above sea level with the duration of one cropping season for 2021 – 2022.

Experimental Design and Treatments

The experiment was laid out in Randomized Complete Block Design (RCBD)and replicated three times. The experimental dimension is 4 x 5 meters, and a space of 0.5 meters for alleyways between replications. Treatment was as follows:

T_1 = Farmers Practice

T_2 = Recommended Rate of Fertilizers (RRF) Application,

T_3 = Soil Inoculant,

T_4 =Foliar Fertilizer alone (Carrageenan),

T_5 = Soil Amendments combined with soil Inoculants (CRH and *Bacillus amyloliquefaciens*)

T_6 = Foliar Fertilizer combined with soil inoculant

T_7 = 50% RRF combined with Foliar Fertilizer and soil inoculant and

T8 = 50% RRF combined with soil inoculant

Soil Collection, Sampling and Analyses

Composite soil samples were obtained from the experimental area as initial soil samples. Spades were used to collect soil samples from the experimental area at a depth of 30 cm. Fifteen subsamples were collected from the entire site following the zigzag method. Air-dried samples were thoroughly mixed, pulverized finely, and sieved. A kilo of composite samples was brought to the Regional Soils Laboratory of the Bureau of Soils and Water Management, Davao City, to analyze the following soil parameters as soil pH, N, P_2O_5, K_2O, soil organic matter (SOM), and zinc, calcium, magnesium, iron, sodium, and silica micronutrients. The same procedure was done upon the termination of the study.

Fertilizer and Treatment Application

This study followed the farmer's practice of slash and burn system for upland rice production. At the same time, Foliar Fertilizers (irradiated carrageenan) were applied based on the recommended rate of 20ml//L (DOST-PCARRD) as drench application. In contrast, soil inoculant (*Bacillus amyloliquefaciens*) application was diluted with water with a recommended rate of 100g/100L and applied in the ground around the plants 15 days after sowing (DAS) up to 60 DAS panicle initiation to the booting stage. Soil Amendments (Carbonized Rice Hull) were incorporated during land preparation at a rate of 4.31 kilos per square meter (IRRI, 2021). Treatments with inorganic fertilizers were based on the analysis and divided into three applications. Based on soil analysis, the fertilizer recommendation and application rate were 90-45-60 kg N, P_2O_5, and K_2O per hectare. The materials used were complete fertilizer (14-14-14) and urea (46-0-0) and muriate of potash (0-0-60). Complete fertilizer at 642.86 grams and urea at 97.82 grams and muriate of potash (MOP) at 50g per plot, was applied 15 days after sowing (DAS), 35 DAS side-dress application, and 45 DAS at the panicle initiation stage of the crops.

Cultural Management

The study area was tilled and cultivated to make it suitable for rice production. Eighty (80) grams of NSIC Rc27 were sown per treatment plot based on the 40 kg/ha seeding rate. Pre-emergence herbicide was used with a rate of 1.5 kg active ingredient/ha and was applied seven days before sowing following the recommended dose. Supplementary hand weeding was done when weeds were still inside the

Figure 1: Land Preparation and Experimental Layout of Upland Rice Production

research plot. Post-emergence herbicide with a rate of 1.3L/200L of water per hectare was also sprayed in the alleyways between plots to remove the weeds. The areas were infested with common rice pests and diseases during the panicle and stiff dough stage; a 50g/L-cypermethrin was applied twice when the plants were most sensitive to pests and diseases. Harvesting occurred when 85% of the grain turned golden yellow, yellowish, or fully matured ripe. Harvesting was manually done utilizing a sickle except for two border rows in each plot and end plants at 25 cm linear length at the end of each plot; all sample panicles from the harvestable area were harvested. The sample panicles were manually removed using barefoot, winnowed, sundried for three days, and winnowed before gathering all the necessary data.

Data Collection and Analysis

Data was collected at ten (10) randomly selected hills at various stages of the rice growth cycle. Meteorological data were gathered together with soil analysis before and after the experiment. Agronomic data such as plant height in centimeters (cm), number of tillers, and number of productive tillers were recorded every two weeks and during termination, respectively. At the harvest stage, yield parameters such as the number of panicles per square meter, number of filled grains per panicle, weight of 1000 grains, and grain yield per hectare were measured. Data collected were analyzed using analysis of variance (ANOVA), and means were compared using Honest Significance Difference (HSD) at a 5% significance level. All statistical analyses were performed using the statistical software Statistical Tool for Agricultural Research (STAR) developed by IRRI.

RESULTS AND DISCUSSION

Meteorological Data and Soil Chemical Analyses

Total monthly rainfall in millimeters (mm), average monthly minimum and maximum temperatures in Celsius (°C), and relative humidity (%) were extracted from the data (http://www.accuweather.com/rainfall - in- Compostela).

Data showed (Fig. 2) that the total precipitation during the trial reached 889.5 millimeters (mm) and had an average air temperature ranging from 24.77°C to 32.10°C; this data was below the optimum requirements for upland rice cultivation for its average growth and development that needed 1,200mm – 1,500mm of precipitation and 20 – 35°C from planting to harvesting (Toung & Bouman, 2003).

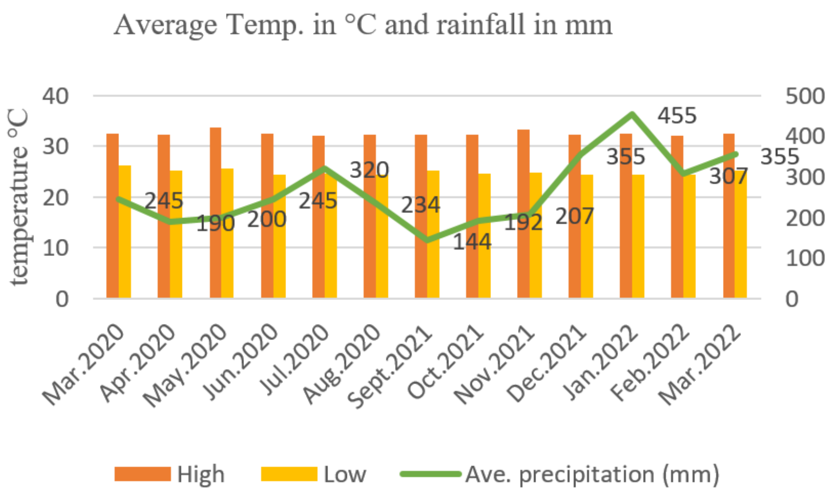


Figure 2: Average temperature (°C), precipitation (mm), and humidity (%) of Maparat Compostela, Davao de Oro

Initial soil analysis results showed that the area was strongly acidic (pH of 5.0), low in organic matter (1.10%), deficient in available phosphorous (2.34ppm), and low in exchangeable K (68.19ppm) Zn level (1.0ppm), and has nitrogen recommendation (45kg/ha).

Soil analysis after termination showed slightly decreased soil pH in plots treated with synthetic fertilizers and plots with combined soil inoculants ranging from 4.7 to 4.8. In contrast, treatment with soil amendments slightly increased to 5.1, respectively.

The final soil analysis results observed a slight pH decrease after the upland rice harvest. An increase in potassium (K) level was observed after harvesting in the plot applied with synthetic fertilizers (T_2 and T_7) due to residual effects and crop residue present in the soil. A decrease in exchangeable phosphorus (P) might be due to the accumulation of soluble salts present in the area, which increased pH, as mostly happened in highland regions, and the expected results of applying synthetic fertilizer. The decrease in P could be attributed to plants' utilization for growth and development (Henan *et al.,* 2004).

Changes in nutritional characteristics indicate that the plant uses the nutrients available in the soil. The increase in organic matter helps improve soil health. Soils with higher organic matter content and better cation exchange capability provide more significant buffering and reduce the risk of mineral imbalances induced by haphazard fertilizer (Schroupfer *et al.,* 2018).

Soil pH indicates hydrogen activity in the soil solution, influencing the availability of mineral nutrients for plants.

Table 1: Before and After Soil Chemical Characteristics in Upland Rice Production using Soil Inoculants, Soil Amendments, and Foliar Fertilizer

Parameters	**Unit**	**Number of Analysis**		**Methodology**
		Initial Analysis	**Final Analysis**	
Soil pH	-	5.0	4.8	Glass electrode
Soil Organic Matter (SOM)	%	1.10	1.36	Walkey-Black
Total N	%	0.23	0.23	Kjeldahl
Available P	ppm	2.34	3.65	Modified Troug
Exchangeable K	ppm	68.19	68.64	H2SO4 extraction
Zn	ppm	1.0	1.08	Extraction-AAS
Calcium	ppm	115.68	110.45	Extraction-AAS
Magnesium	ppm	30.90	12.34	Extraction-AAS
Sodium	ppm	3.00	1.80	HClO4 Digestion
Chlorine	ppm	0.09	0.03	Argentrometric
Boron	ppm	ND	ND	Carmine

*Abbreviation: *ppm – part per million, ND = non detectable*

Findings indicated that most soil profiles exhibited pH values in water ranging from 5.0 to 7.0, with a slight tendency toward acidity that may limit plant growth. KCl pH levels were notably highly and strongly acidic (5.0 to 5.8), signifying an overall acidic soil reaction less conducive to crop development (Landon, 1991).

The results suggested that acidification occurs with crop cultivation, a consequence of nutrient losses during crop removal, indicating soil pH as a potential indicator of chemical soil degradation. However, native plants on the site demonstrated resilience to the acidic soil in degraded uplands (Asio *et al.,* 2014, 2015). Additionally, soil pH levels in different profiles increased with depth; surface horizons were more acidic than subsurface horizons, likely attributed to higher organic matter content from leaf litter and other materials. The decomposition of these organics generated acids, contributing to the surface horizon's increased acidity (Genenew, 2008).

Mikkelsen (2010) noted that Mg is typically second in abundance to Ca on cation exchange sites in alkaline to slightly acidic soils. Magnesium ions behave similarly to calcium in ion exchange reactions, which are reversible, allowing strongly adsorbed cations to be replaced by manipulating the soil solution.

Agronomic Characteristics

Plant Height in centimeters (cm)

The combined application of soil inoculant and synthetic fertilizers obtained the highest plant height during the entire conduct of the study from 15DAS – 75DAS except

Table 2: Plant height mean in centimeters of Upland Rice in 15, 30,45, 60, and 70 DAS

Treatments	**Plant height (cm)**				
	15 DAS	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**
T_1 – FP	8.17^{a}	17.41^{c}	28.67^{e}	44.25^{d}	67.75^{d}
T_2 – RRF	8.50^{ab}	18.92^{b}	32.92^{bc}	58.58^{b}	80.75^{b}
T_3 – SIA	8.58^{ab}	17.83^{c}	29.75^{de}	49.42^{cd}	72.25^{c}
T_4 – FFA	8.53^{ab}	18.91^{b}	31.16^{cd}	49.33^{cd}	72.5^{c}
T_5 – Combination of SIA and SAA	8.42^{ab}	17.50^{c}	28.33^{e}	43.75^{abc}	68.00^{d}
T_6 – Combination of SIA and FFA	8.42^{ab}	17.33^{c}	28.33^{e}	44.92^{bc}	67.42^{d}
T_7 – Combination of 50% RRF, SIA and FFA	9.25^{a}	20.25^{a}	35.50^{a}	64.58^{a}	86.17^{a}
T_8 – Combination of 50% RRF and SIA	8.75^{ab}	19.50^{ab}	33.83^{ab}	62.75^{ab}	82.16^{b}
	ns	ns	ns	**	*
p-value	0.35	0.91	1.09	14.55	7.81
CV (%)	10.62	9.92	22.72	5.93	8.29

FP = Farmers Practice, RRF = Recommended Rate of Fertilizer Application, SIA = Soil Inoculant Application, SAA = Soil Amendment Application, FFA = Foliar Fertilizer Application

This means a column followed by the same letter is not significantly different using Tukey's Honestly Significant Difference (HSD) p>0.05. ns= denotes not significant DAS = Days After Sowing on 15, 30, and 45 Days After Sowing (DAS). Nevertheless, it gives significant results based on the Analysis of Variance (ANOVA) on 60 and 75 DAS, respectively.

Plot treated with 50%RRF with foliar and soil inoculant (T_7) and plot applied with 50% RRF added with soil inoculant application(T_8) together with plots applied with synthetic fertilizers (T_2) consistently give significant results among other treatments.

The lowest plant height in centimeters was seen in the slash-and-burn (conventional) farmers' practice (T_1) throughout the study.

This result was linked to synthetic fertilizers, whether complete or less application, which are proven to increase the growth and development of plants within a short period as they are readily available for the plant to uptake. On the other hand, plots applied with inoculants can promote plant growth with a minimal effect as it has a slow-releasing impact (Company *et al.,* 2010).

While treatments applied with soil amendments and foliar fertilizers (CRH and carrageenan) (T_5) and (T_6) affect only the soil's physical, chemical, and biological properties by enhancing the moisture-holding capacity and promoting the growth of beneficial soil microbes (Sandrini, 2010; Ertani *et al.,* 2013) that may result to better absorption of soil nutrients by increasing soil porosity. These findings indicated that extended surface area and porous pores should improve physical properties (Chand *et al.,* 2009). In principle, the threshold dose depends on the effects of rice hull ash on the soil properties. It can increase the pH and nutrient availability (Sandrini, 2010; Silva, 2008). Furthermore, CRH was primarily consists of silica (90-95%), as well as minor amounts of calcium magnesium, potassium, sodium, phosphorus and sulfur and amounts of aluminum, manganese and iron (Rao *et al.,*1989) resulting to lesser effect on growth of rice.

Additionally, when foliar fertilizer (carrageenan) is applied to the crops and the soil, it increases the biomass and activity of microbes, soil respiration, and soil fertility (du Jardin, 2015).

Figure 3: Upland rice during the soft dough stage

Yield and Yield Components

Number of Productive Tillers, Days to Maturity, and Panicle Length

Among the eight treatments, plots applied with synthetic fertilizers, whether RRF (T_2), combined with SIA, SAA, and FFA (T_7), (T_8), consistently show no significant results among each other based on ANOVA. Nevertheless, compared to plots without synthetic fertilizers, it is statistically significant.

These data trends were seen in yield parameters of the number of productive tillers, days to flower, and panicle length in centimeters (Table 2), in contrast to conventional farming practice (T_1), which gives the lowest data in all parameters.

Table 3: Agronomic data of Upland Rice based on the number of Productive tillers, Days to flower, and panicle length in centimeters (cm)

Treatments	Yield Parameters		
	No. of Productive Tillers	**Days to Flower**	**Panicle Length in centimeters (cm)**
T_1 – FP	7.00^{c}	87.00^{bc}	13.00^{d}
T_2 – RRF	14.00^{a}	90.00a	30.00^{a}
T_3 – SIA	8.00^{c}	87.00^{bc}	17.30^{c}
T_4 – FFA	9.00^{bc}	87.00^{bc}	16.30^{c}
T_5 – Combination of SIA and SAA	8.00^{c}	86.00^{c}	23.67^{b}
T_6 – Combination of SIA and FFA	10.00^{abc}	87.00^{bc}	23.33^{b}
T_7 – Combination of 50% RRF, SIA and FFA	13.00^{ab}	88.00^{abc}	29.67^{a}
T_8 – Combination of 50% RRF and SIA	12.00^{abc}	89.00^{ab}	30.67^{a}
	*	*	**
p-value	8.52	7.31	254.97
CV (%)	16.19	0.95	3.23

FP = Farmers Practice, RRF = Recommended Rate of Fertilizer Application, SIA = Soil Inoculant Application, SAA = Soil Amendment Application, FFA = Foliar Fertilizer Application

This means a column followed by the same letter is not significantly different using Tukey's Honestly Significant Difference (HSD) p>0.05.

On several productive tillers, plots applied with synthetic fertilizers, whether RRF (lesser or total amount) or combined with SIA and FFA, have a more significant number of production tillers among treated plots ranging from 10 to 14 tillers.

Recommended Rate of Fertilizers (T_2) recorded longer days to flower with 90 DAS, while SIA and SAA applied plots had earlier average days to flower with 86 DAS.

Panicle length in centimeters (cm) was seen highest in plots with synthetic fertilizers with a length of 29.67cm to 30.67cm; opposite results were seen in FP and SIA and SAA combination ranging only from 13.0 – 17.3cm.

Results signify that the readily available nutrients from synthetic fertilizers were taken by plants, resulting in higher agronomic and yield parameters due to more excellent plants' nutrient absorption capacity.

Fuentes (2010) pointed out that organic fertilizer combined with synthetic fertilizers could help plants attain their maximum growth and yield as it is a valuable source of macronutrients NPK and essential elements plants need. In a study, Untalan (2017) also confirms that supplementing SIA in fewer or greater synthetic fertilizers can enhance lowland rice's agronomic and yield parameters.

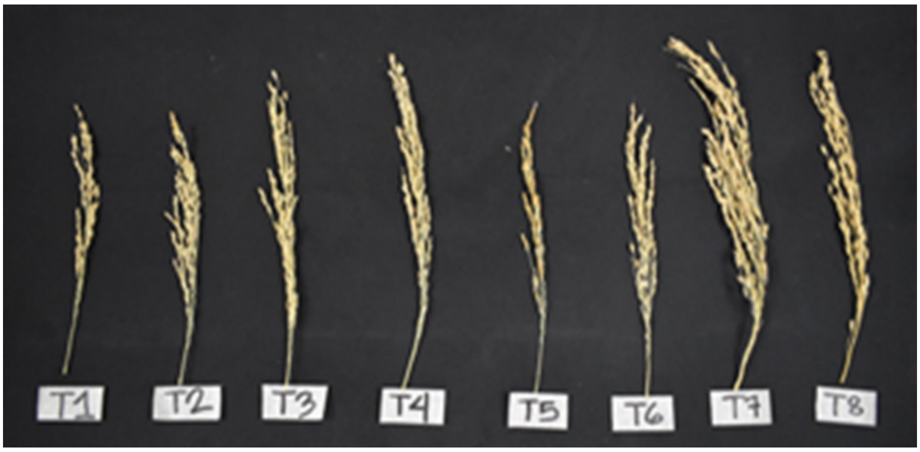


Figure 4: Panicle length and visual volume of grain per panicle

Number of Filled Grains per Panicle and Weight of 1000 grains in 14%MC

The same data trend was seen (Table 3) on average grains per panicle, number of filled grains, weight of 1000g grains, and 1m by 1m yield in grams. In contrast, treatment with RRF and its combination with SIA and FFA show no significant result among each other. However, it gives statistically significant outcomes compared to FP (conventional farming practices), SIA, and FFA, among others, based on Analysis of Variance (ANOVA).

Aside from abiotic factors, biotic factors such as pests and diseases also contribute. The number of filled grains was associated with 1000 grains, where plots treated with 50%

Table 4: Plant height mean in centimeters of Upland Rice in 15, 30,45, 60, and 70 DAS

Treatments	**Yield Parameters**			
	Ave. Grains per panicle	**Number of Filled Grains per Panicle**	**Weight of 1000 grains in grams (g) at 14%MC**	**1m x 1m yield crop cut in grams (g)**
T_1 – FP	30.00^c	18.00^c	22.430^e	53.00^c
T_2 – RRF	248.00^a	174.00^a	29.910^a	1167.70^a
T_3 – SIA	57.00^c	35.00^c	23.860^d	112.30^c
T_4 – FFA	41.00^c	26.00^c	24.080^d	95.70^c
T_5 – Combination of SIA and SAA	106.00^b	72.00^b	23.780^d	218.30^c
T_6 – Combination of SIA and FFA	103.00^b	67.00^b	24.030^d	247.70^c
T_7 – Combination of 50% RRF, SIA and FFA	253.00^a	176.00^a	26.92^c	988.00^{ab}
T_8 – Combination of 50% RRF and SIA	236.00^a	161.00^a	28.43^b	870.30^b
	**	**	**	**
p-value	134.87	130.95	352.32	90.17
CV (%)	10.67	11.37	0.96	17.82

FP = Farmers Practice, RRF = Recommended Rate of Fertilizer Application, SIA = Soil Inoculant Application, SAA = Soil Amendment Application, FFA = Foliar Fertilizer Application

This means a column followed by the same letter is not significantly different using Tukey's Honestly Significant Difference (HSD) p>0.05.

RRF combined with *Bacillus amyloliquefaciens* added with carrageenan had the highest massive weight of 31.90g. This result was comparable to T_2 with 30.40g, followed by T_8, T_1, T_6, T_4, and T_3 with 27.17g, 26.93g, 26.00g, 25.40g, and 24.5g respectively. Results could be attributed to the absorption of nutrients available in the soil and the grain size.

The same data trends were observed in parameters such as the average number of grains per panicle, percentage of filled and unfilled grains, weight of 1000 grains at 14% MC, and yield in tons per hectare differed significantly (Table 4).

On the percentage of filled grains, the study revealed that filled grains per panicle range from 60 - 71%. Plots applied with 50% RRF combined with SIA and FFA (T_7) and (T_8) marked the highest filled panicle grains.

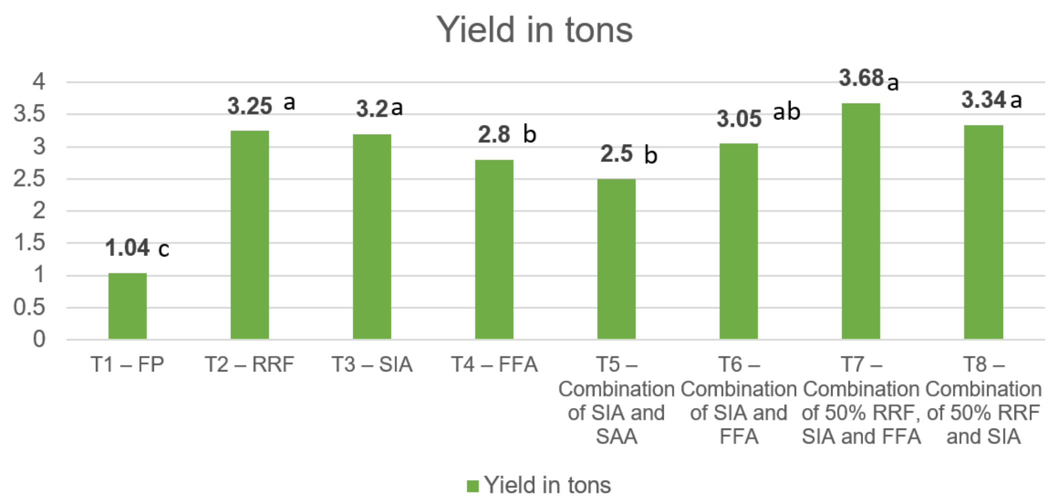
Results signify that the readily available nutrients in synthetic fertilizer, whether in whole or small amounts, significantly improve the experimental crop's yield parameters.

Besides the plants ' nutrient absorption capacity, several factors were considered in developing rice-filled grains, such as rainfall, humidity, and temperature (IRRI, 2019).

Yield in Tons Per Hectare (t/ha)

The yield of treatment was presented in Figure 3, where treatments with RRF (less or complete application) and plots applied with soil inoculants, foliar fertilizers, and soil amendment, whether combined or applied alone, give significant results compared to farmers' practice.

These treatments recorded yields ranging from 2.5 – 3.68 tons per hectare. These results were seen higher from farmers' practices, with a 1. 46 – 2.64 tons yield increase. The 50% RRF, SIA, and FFA combination yielded higher



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This means a column followed by the same letter is not significantly different using Tukey's Honestly Significant Difference (HSD) p>0.05.

Figure 5: Yield Comparison of Upland rice treated with Selected Soil Inoculants, Soil Amendments, and Foliar Fertilizer

yields. This result was not significant to RRF.

The average yield in tons per hectare is linked to the number of productive tillers, panicle length, the number of grains and filled spikelets, and the weight of 1000 grains. The result suggests that all yield and components contributed to the significantly highest grain yield (3.05 t/ha) of plants treated with a combined 50%RRF, SIA, and FFA.

Reports of high but inconsistent increases in yield on different crops when applied with foliar fertilizers (seaweed extract) (Calvo *et al.,* 2014). A study by du Jardin, 2015; and Mariano, 2018 added that foliar fertilizers from seaweed extracts promote plant growth-promoting bacteria and pathogen antagonists in the soils. In addition, they have nutritional effects by providing nutrients to plant tissues, improving nutrient utilization, and enhancing soil aeration and structures that stimulate root growth.

On the other hand, Cruz *et al.* (2015, 2014) confirm that using soil inoculants can lead to better nutrient absorption in upland rice as these minute organisms create a symbiotic relationship with plant roots.

Additionally, findings coincide with the literature that carrageenan is a plant growth regulator (CPGR), increases rice yield at an average of 25-30%, and boosts nutrient absorption (DOST PCAARRD). However, carbonized rice husk improved the soil's physical properties, such as bulk density and porosity. The results of this research imply that carbonized rice husk can be used as a soil amendment for environmentally friendly rice production. Furthermore, Bradey *et al.* (1984) confirm that using readily available nutrients from synthetic fertilizers in the right amount, the right kind, at the right time, and in the proper application improves the yield quality of the crops.

Cost and Return Analysis

Farmers primarily rely on yield and profit to determine the suitability of adopting specific technologies. Rice production is challenged by higher input costs such as fertilizers, erratic weather conditions, and abiotic stress.

Table 4 below shows each treatment's return on investment (ROI) using cost and result analysis; it says that Treatment 3 can achieve as much as 70.89% ROI. This outcome is followed by plots on Treatment 6 with 55.73%, Treatment 5 with 53.72%, and Treatment 4 with only 50.91% ROI.

Lower RPC percentage was seen in plots with Synthetic Application RRF (T2) and Farmers Practice (FP) control plots with 7.71% and 29. 49%, respectively.

Based on the analyzed production and return, plots treated with soil inoculant application (SIA), soil amendment application (SAA), and foliar fertilizer application (FFA) are the cost-efficient treatments.

Table 5: Cost and Return Analysis of the Performance of Selected Soil Inoculants, Soil Amendments, and Foliar Fertilizer in Enhancing Upland Rice Production

Treatments	**Cost and Return Analysis**				
	Yield per hectare in tons	**Price per kilo (PhP)**	**Gross Revenue (PhP)**	**Total Production Cost (PhP)**	**RPC (%)**
T_1 – FP	1.04	19.00	15,994.00	15,994.00	29.49
T_2 – RRF	3.25	19.00	57,670.00	57,670.00	7.71
T_3 – SIA	3.2	19.00	35,578.00	35,578.00	70.89
T_4 – FFA	2.8	19.00	35,252.00	35,252.00	50.91
T_5 – Combination of SIA and SAA	2.5	19.00	30,900.00	30,900.00	53.72
T_6 – Combination of SIA and FFA	3.05	19.00	37,212.00	37,212.00	55.73
T_7 – Combination of 50% RRF, SIA and FFA	3.68	19.00	50,511.00	50,511.00	38.43
T_8 – Combination of 50% RRF and SIA	3.34	19.00	48,006.00	48,006.00	32.19

FP = Farmers Practice, RRF = Recommended Rate of Fertilizer Application, SIA = Soil Inoculant Application, SAA = Soil Amendment Application, FFA = Foliar Fertilizer Application

On the other hand, plots with complete or less application of synthetic fertilizers marked more significant production costs, resulting in lower return of production costs. Enhancing yield and profit is essential. Moreover, the cost and return analysis outcomes will serve as a valuable foundation for business purposes, offering educational insights for farmers interested in entering the business arena.

Results suggest that using Soil Inoculant combined with foliar application FFA (drenching method) favors upland rice production. Sukhla *et al.* (2016) confirm the benefits of using these FFA results to yield better. At the same time, the lower RPC of RRF may attributed to the higher cost of fertilizer in the market.

Results also confirmed in Untalan (2019) reports that supplementing soil inoculant will increase lowland rice production.

CONCLUSION

Based on the result of agronomic, yield and yield components of the study outcomes suggest that selected soil inoculants, soil amendments, and foliar fertilizer can enhance upland rice production; these can be seen in plant height, panicle length, number of productive tillers, filled grains and yield compared to the conventional upland rice farming.

This signifies that upland rice production has the potential to contribute to rice self-sufficiency. Organic fertilizers combined with less synthetic fertilizer supplied with soil microorganisms are the most cost-effective, consistent with prior results for upland rice productivity. It can be an alternative to synthetic fertilizers, which have long-term adverse effects on the land. Aside from enhancing soil organic matter, an indicator of soil health, organic fertilizers, and microbial inoculants supplemented with fewer synthetic fertilizers increase agronomic features, yield, and yield components equivalent to better yield than cultural techniques with no application.

According to the findings, carbonized rice hull (CRH) was used to improve soil microorganisms and quality while having minimal influence on yield.

Carrageenan and Kappaphycus drippings combined with *Bacillus amyloliquefaciens* can be used as foliar fertilizers instead of synthetic fertilizers, showing great promise in improving upland rice production and pest control.

The researcher proposes a different cropping and study site location to validate the findings further. In addition, another season under marginal upland acid soil conditions with pest infestations could also be included in the study for future research projects. Furthermore, the researcher recommends evaluating the potential of using carbonized rice hulls in soil improvement in upland conditions due to their low cost and accessibility.

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