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YIELD RESPONSE OF SELECTED RICE VARIETIES TREATED WITH DIFFERENT PHOSPHORUS LEVELS AND MYCORRHIZAE SP

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ABSTRACT

This study was conducted to evaluate the yield performance and yield response of selected rice cultivars to applying different levels of Phosphorus and Mycorrhizae sp. under potted conditions coinciding with typical rice production conditions. A three-level factor experiment, namely method of seed treatment (seed coating and seed biorpiming) as the main treatment, rice varieties (NSIC Rc 222 and NSIC Rc 480) as subplot treatment, and Mycorrhizae + levels of Phosphorus (0, recommended P (RP), recommended Mycorrhizae, M+50% of RP, M+100% RP and M+150% of RP) as sub-sub plot treatment replicated four times was executed. Results of yield parameters such as the number of productive tillers, panicle/hill, filled grains, yield, harvest index, and yield were analyzed using Analysis of Variance (ANOVA) and differentiated using Least Significant Difference (LSD) test and Tukey's Honest Significant Difference (HSD) test. The introduction of M+50% of RP or Mycorrhizae sp. alone (M) through seed-coating or seed biopriming during the early stage of plant development enhanced tillering formation and the development of productive tillers of NSIC Rc 222 and NSIC Rc 480. Combining 50-100% P with Mycorrhizae, whether applied as the seed coat or bioprimed improved P concentration compared to inoculating M alone. The application of Mycorrhizae with 50-100% P improved yield in terms of the number of panicles per hill, weight of grains, yield per hill, yield per hectare, and harvest index when applied as a seed coating resulting to two-to-four-fold increase. Further, the addition of 50% P with a recommended rate of M increased plant yield with comparable output with applying P alone. Lastly, combining Mycorrhizae sp. as seed treatment with 50% P incurred 38.11 to 44.92% increase in income of farmers. Further addition synthetic fertilizer combined with microbes limit the yield of rice under lahar-laden P-limited soil.

Keywords: phosphorus-deficit, mycorrhizae, seed coating, seed biopriming, nutrient uptake, microbial growth

1) INTRODUCTION

Rice remains the dominant staple of Filipinos. The Philippines is producing 7.16 million metric tons of rice, sustaining millions of Filipino families (PSA, 2019). As the Philippines is steadily growing rice, rice consumption also increased faster than domestic production? This condition creates a supply gap since the local production cannot meet the growing demand.

Recently, rice production in the Philippines is still grown through mono-cropping. In irrigated and rain-fed areas, it is highly dependent on continual inputs of synthetic-based fertilizers. Despite technological breakthroughs in rice research, farm yield levels are still way below their maximum potential due to biological, technical, physical, and policy constraints. Rice production in 2018 gradually dropped by 1.8% compared to the previous rice yield obtained per hectare (PSA, 2019). The incurred reduction is associated with environmental factors as well as the increasing cost of field inputs. Fertilizer use contributes to a large portion of rice production expense equivalent to PhP 2.41 cost of fertilizer to produce a kilogram of rice (PSA, 2020). Another reason for declining production yield is the depletion of soil fertility. Under the farmer's field at a fixed level of fertilizer, productivity has been going down, and to produce

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a higher yield, a higher level of fertilizer must be added. This condition may result in the accumulation of unexploited elements leading to the resource base's degradation and pollution.

Soils in rice-producing areas of Central Luzon, specifically the lahar-laden areas, are generally deficient in Phosphorus (P), which is one of the principal macronutrients for growth yield development. Currently, rice production in the region is majorly dependent on synthetic Phosphorus and other nutrients resulting in a higher production cost.

The depletion of global Phosphorus reserves has elevated the concerns for global food production nowadays. Large-scale breeding of rice varieties that can continuously grow in Phosphorus-deficient soils or enhanced Phosphorus fertilizer use efficiency is now recognized and given importance in the rice research sector (Chin et al., 2011). However, due to the long period of screening varieties for Phosphorus-deficient soils, various techniques are recommended to enhance Phosphorus uptake. The use of mixtures of organic manures, inorganic fertilizer, and microbial inoculants, whether or not affected by climate change (Wu & Ma., 2015; Wu, Chang & Lur, 2016), promised significant potential. Enhancing the soil's microbial load with a fixed fertilizer level could reduce nutrient loss due to sudden climate change or exposure to extreme weather events.

The efficient use of nutrients is well-studied in improving rice yield and quality under drought conditions (Chin, 2011; Rose et al., 2012), but the interaction of nutrients like Phosphorus and beneficial microorganisms are inadequate for rice production under different agro-ecological zones. Limited studies revealed that available Phosphorus content increased in rice production in complementation with microorganisms such as Mycorrhizae sp. Combining microorganisms' work in converting nutrients efficiently for plant use with the efficient application of fertilizer could lessen the amount of input applied without sacrificing the crop's productivity and the land. Using the various fertilizers in other forms such as seed coating and seed bioprinting in rice and rice-based cropping systems is scarce. As the country faces climate variability challenges throughout the years, it is high time in developing techniques for effectively utilizing nutrients from the soil without sacrificing crop yield and quality. More so, cost-effective technologies are deemed necessary for our current situation.

The introduction of Phosphorus and Mycorrhizae sp. to plants comes in many ways. The most cost-effective technique is seed treatment. Seed coating and seed bio priming are the two most promising nutrient and microbial introduction techniques to the early stage of plants. Starter nutrients to plants with microbes augment the absorption of soil-available nutrients for efficient use. Increasing microbial load to soil ecosystem where the plant grows permits Phosphorus efficiently together with other slowly absorbed nutrients for plant use that will result in more excellent plant resistance and improved yield.

Seed coating and seed priming with microorganisms, also called bio priming, are two techniques that can be applied for cereals to introduce fertilizers to plant at early stages to replace Phosphorus's surface broadcasting or point of placement technique. Seed coating used soluble components wrapped into small seeds before planting (Madsen et al., 2016), while bio priming takes advantage of the imbibition of fertilizer and microorganisms in liquid form

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(Mahmood, Turgay, Farooq & Hayat, 2016). One study showed that arbuscular Mycorrhizae fungi (AMF) application boosted plant growth and yield, whether applied as seed coating or basal application under lahar-laden areas (Baysa et al., 2018). Although seed coating and seed bio priming are practiced for cereal and vegetable production, limited information is available whether seed coating or seed bio priming are suitable methods of meeting early Phosphorus demand and improving the yield of rice varieties suited to various growing conditions such as irrigated and rain-fed rice production (Baysa et al., 2018).

Most smallholder rice farmers are resource-poor and cannot afford P-containing fertilizer inputs to increase crops' yield on infertile soils. Incomplete fertilizer application often leads to low production. Identifying the appropriate P levels in combination with mycorrhizae on rice seeds will increase plant available P. Furthermore, identifying the most suitable fertilizer application method will help farmers improve their fertilizer requirement and regime towards rice production. Additionally, P levels and Mycorrhizae's introduction to plants using bio-priming or seed coating will reduce farms' input expenditure to more than 50% of fertilizer input without sacrificing rice yield suitable low-budget farming.

Objective

This study evaluated the yield performance of two rice varieties applied with Phosphorus and Mycorrhizae sp. using varying levels and seed treatment techniques on P limited soil. Moreover, this study intended to answer if there are variations in yield and yield response of selected rice varieties when treated with different Phosphorus levels and Mycorrhizae sp. subjected to two different seed treatments.

2) METHODOLOGY

1. Conceptual Framework

Crop production is highly dependent on fertilizers for efficient and profitable production (Cordell et al., 2009). Fertilizers provide the three major nutrients like Nitrogen (N), Phosphorus (P), and Potassium (K), which plants primarily needed. Phosphorus is the most critical and limited component on large proportions of arable lands (Cordell et al., 2009), and it is a diminishing resource (Vance et al., 2003). Phosphorus is essential for the stability and continued survival of plants. Phosphorus primarily functions for many plant physiological processes, such as photosynthesis, respiration, and energy transfer. Plants need a sufficient amount of available Phosphorus during the early growth stages to give maximum yield (Grant et al., 2005). Phosphorus' direct availability defines plant growth, and a limited supply of Phosphorus results in crop yield loss (Hinsinger, 2001). Thus, Phosphorus should be made available at the early stage of growth to enhance crop production. Because of Phosphorus properties' uniqueness, acquisition of the element by varying roots architecture and the association with microbes such as Mycorrhizae sp. Controlled its availability to plants. Different approaches, such as the use of microorganisms, are introduced to address Phosphorus insufficiency. Mycorrhizae sp. can significantly enhance Phosphorus uptake. Mycorrhizae sp. and Phosphorus uptake are mutualistic symbiotic associations based on reactive nutrient

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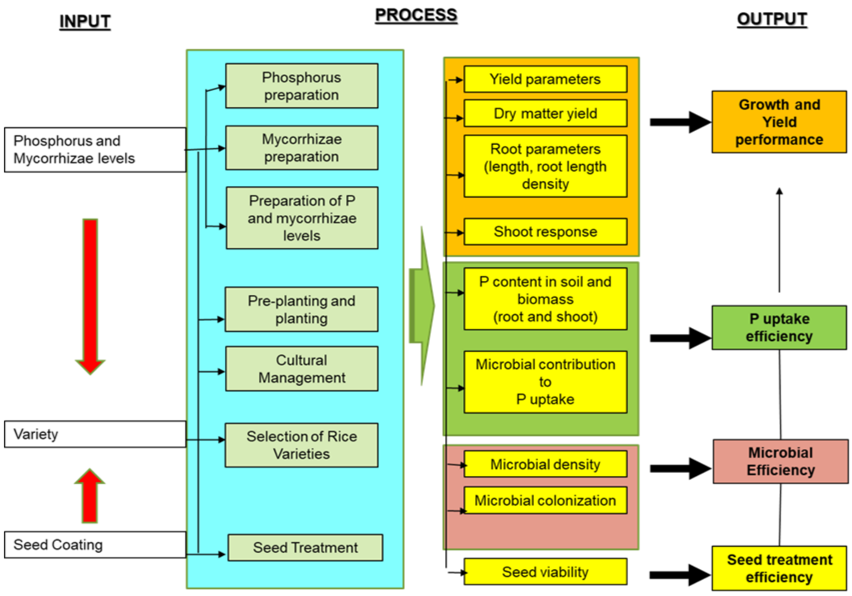
movement between soil fungi and plants' roots. The plant photosynthates serve as food for the fungi (Muchoka et al.), while the fungal mycelia improve the plant's capability to absorb water and nutrients (Planchet et al., 2005; Smith & Read, 2008; Smith & Smith, 2011). Mycorrhizae sp. symbioses contribute significantly to plant nutrition, particularly Phosphorus uptake (Smith et al., 2011; Lecomte et al., 2011; Raklami et al., 2019). Limited information is known on improved Phosphorus nutrition by AM fungi for plants (Ortas et al., 2019). Mycorrhizae symbioses are most frequently recognized to enhance uptake of other nutrients (such as Nitrogen, zinc, and Potassium) and enhance symbiotic Nitrogen-fixation ability. The introduction of Phosphorus and Mycorrhizae sp. to plants comes in many ways. The most cost-effective technique is through seed treatment. Seed coating and seed biopriming are the two most promising nutrient and microbial introduction techniques to the early stage of plants. Starter nutrients to plants with microbes augment the absorption of soil-available nutrients for efficient use. Increasing microbial load to soil ecosystem where the plant grows permits Phosphorus efficiently together with other slowly absorbed nutrients for plant use, resulting in more excellent plant resistance and improved yield. Potentially Phosphorus-efficient cultivars are developed through manipulation of the root system plasticity. Nuruzzaman et al. (2005) and Campos et al. (2018) hypothesized that Phosphorus-acquisition efficiency in plant species relies on the roots' ability to acquire Phosphorus from the soil. Plants vary in the Phosphorus-absorbing capacity of their roots and have inter-specific variations. When a plant is Phosphorus deficient, the Phosphorus absorption or Phosphorus influx rate and the proportion of dry mass increase and Phosphorus content increase affect plant growth (Haynes et al., 1991; Koide, 1991). Thus, this study is interested on finding out the potentiality of utilizing microbes as enhancer in Phosphorus uptake under limited P soil condition and its effect to yield of rice.

Figure 1: Conceptual Framework



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2. Materials and Methods

a. The locale of the study

The conducted experiment is located in an open-field lahar-laden rice production area situated at Carael, Botolan, Zambales. Carael, Botolan was submerged to lahar in 1991 and left unproductive until 2010. The site has a 20-30 cm depth lahar. Botolan, Zambales has a monthly average temperature of 25-27°C from November to February and a 0.5 to 1°C increase in temperature from March-April. The area is rain-fed and only supplemented with pumped irrigation during the dry season. Based on soil analysis conducted, the soil contained the following nutrients (DA-Regional Soils Laboratory, 2019) and was identified as P-deficient soil (Appendix Figure 1):

1. Primary nutrients
   - a. Organic matter (Colorimetric method) : 0.03%
   - **b. Phosphorus (Olsen's Method) : 5.15 ppm**
   - c. Potassium (Cold H_2SO_4 Extraction) : 58.50 ppm
2. Micronutrients (DPTA Method)
   - a. Zinc : 0.14 ppm
   - b. Copper : 1.11 ppm
   - c. Manganese : 5.54 ppm
   - d. Iron : 9.30 ppm
3. Texture : Light
4. Acidity (pH) : 7.32
5. Nutrient recommendation (Inbred rice)
   - a. Dry season : 90 - 40 - 30
   - b. Wet Season : 80 - 40 – 30
   - c. Zinc sulfate application : 20 kg/ha

b. Experimental design, treatments, and layout

An open field pot experiment was conducted in a 200 square meters rice field of Carael, Botolan, Zambales from January – May 2020, simulating the regular rice production management practices. The influence of Mycorrhizae sp. (M) and concentration levels of Phosphorus application and seed treatment techniques on P uptake, growth, and yield of selected rice varieties were examined. The identified treatments were replicated four times and laid out using Split -split-plot in CRD experimentation. Each replicates represented with ten rice plants. Three factors were measured: the application method as the primary treatment, rice

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varieties as subplot treatment, and Phosphorus levels, and mycorrhizae as sub-sub plot treatment. Detailed treatments were as follow:

Main plot treatment (S) – Seed treatment

S1 – Seed coating

S2 – Seed bio-priming

Sub-plot Treatment (V) – Inbred Rice Varieties

V1 – NSIC RC 222 (Irrigated variety)

V2 – NSIC RC 480 (Drought-tolerant variety)

Sub-sub plot Treatment (P) - Phosphorus-Mycorrhizae sp. combination

P1 – Control (no P and Mycorrhizae sp. application)

P2 – Recommended Phosphorus alone (RP)

P3 - Mycorrhizae sp. alone (600g/h)

P4 - 50 % of RP + Mycorrhizae sp.

P5 - 100 % of RP + Mycorrhizae sp.

P6 – 150% of RP + Mycorrhizae sp.

Pot experimentation with a customized design of 8x8x16 inches polyethylene (PP) pot set-up utilized to monitor test plants' growth and development. Nine hundred sixty (960) improvised pot set-ups were provided for the experiment. All treatments were supplemented with recommended nutrients such as Nitrogen (195.65 kg/ha) and Potassium (50 kg/ha) except Phosphorus.

c. Treatment Application

1. Experimental Crops

The two rice varieties were selected based on different rice ecosystems grown, such as irrigated and rainfed, and farmer preference for better yield. Certified seeds of NSIC Rc 222 were sourced from the Department of Agriculture-Regional Field Office, Pampanga, and the NSIC Rc 480 was purchased from Philippine Rice Research Institute, Nueva Ecija. The root characteristics to adapt to the specific condition of rice were considered. The following are characteristics of selected rice varieties (PhilRice, 2018):

NSIC Rc 222 - NSIC Rc222 (Tubigan 18) is among the inbred varieties suited for the irrigated lowlands. It yields 6.1 -10 tons/hectare when transplanted and 5.7-7.9 tons/ha when direct-seeded. The crop matures in 106-114 days from seeding. NSIC RC 222 is intermediately resistant to blast, bacterial leaf blight, and tungro and moderately resistant to brown planthopper and green leafhoppers (PhilRice, 2020).

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NSIC Rc 480 - NSIC Rc 480, known as GSR 8, is an inbred variety released by IRRI that is drought-tolerant. It yielded an average of 3.224 to 4.40 tons/ha during the wet season and produced a maximum of 94 tillers/hill. The GSR is a variety resistant to abiotic stresses such as drought, salinity, alkalinity, and iron toxicity. It matures 107 to 121 days after sowing and has intermediate resistance to pests (PhilRice, 2020).

2. Fungal Inoculum (Arbuscular Mycorrhizae) Preparation

The fungal inoculum utilized in this Study is Glonus sp in the inoculated substrate. The fungus was purchased from BIOTECH, Laguna. The fungal inoculum has shown a positive effect on rice varieties' yield, especially when coated (Baysa et al., 2017). Before treatment, fungal spore count was done to ensure target arbuscular Mycorrhizae in the substrate. Briefly, about one (1) gram of the inoculated sample was subjected to microscopic examination and established a range of two (2) to three (3) infective spores present per gram of substrate utilized.

3. Preparation of Phosphorus and Mycorrhizae Levels

Different concentration levels of single phosphorus fertilizer (0-22-0) (0, RP, 50% of RP, 100% of RP, and 150% of RP) prepared. The amount of P utilized for seed coating and biopriming was computed and presented in Table 1 based on the result of soil analysis following the dry season recommendation on a per post basis (15kg soil, dry weight):

Table 1: The computed concentration of Phosphorus for seed inoculation

P level	Rate per hectare (kg/ha)	Seed inoculation (g/20 seeds)
1. 50% of RP	90.91	0.620
2. Recommended P (RP)	181.82	1.239
3. 150% of RP	272.73	1.859

The recommendations were computed from 90-40-30 dry-season recommendations using 0-22-0 fertilizer (Duofos).Seed inoculation rate calculated from the estimated amount of seed covered per kilogram soil and normal farming condition of 50-kg seed capacity per hectare-based planting.

Briefly, each treatment level of Phosphorus is pulverized in a mortar and pestle. The computed amount of required fertilizer for each P level was mixed with 10g Mycorrhizae (30 spores) and stored separately in sealed plastic bags to prevent oxidation. For the single application of Mycorrhizae and Phosphorus, prepared materials were sealed independently.

4. Method of Application/Seed Treatment

Before seed treatment application, rice seeds of selected varieties were tested for germination to ensure seeds' viability to minimize experimentation errors. The germination test was done through the ragdoll method and direct pot germination. Both germination tests resulted in 50-65% germination based on five replication tests.

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a. Seed Coating

The treatment followed Baysa et al. (2018) and Rosa, Hanson, and Mote (2011) with some modifications. Briefly, sorted seeds were dipped first in water for 24 hours. After soaking, seeds coated with pre-mixed Mycorrhizae +P level two to four hours before sowing. The weight of each seed before and after treatment was recorded to determine the level of P coated.

b. Seed biopriming

AMF obtained from BIOTECH, Los Banos, Laguna, was inoculated at 600g/ kg paddy seeds. Seed priming followed the procedural work of Sarika et al. (2013) with modifications. Briefly, seeds were washed with sterile distilled water. Treatment mixture solutions following identified concentrations prepared for soaking treatment. Seeds were soaked in each solution treatment for 24 hours. Then, seeds were rolled on a filter paper to remove excess surface water before sowing. The weight of seeds determined for P imbibition.

d. Cultural Management Practices

1. Land preparation

Before field experimentation, the identified rice land area was plowed twice to remove plant debris and break soil clods evenly. A soil sample from this area up to 40 cm depth was utilized for experimentation. After plowing, the land was harrowed once using a tractor-driven implement. The ground was kept free from weeds until the commencement of the experiment. The area was laid out according to the experimental design. Individual holes capable of containing a 40 cm long plastic container were dug in the area. The land boundary utilized for the study was fenced with galvanized wire against stray animals.

2. Potting of Soil and lay-outing

Soil for potting was collected at a depth of 0-40cm. The soil was sieved through a 5mm mesh screen to remove stones and plant debris. Before seeding, a one (1) kg soil composite sample was subjected to laboratory analysis to determine the nutrient composition, pH, and microbial load to ensure proper application of the required optimum amount of fertilizer determine microbial growth to affect plant growth. Soil samples were subjected to heat sterilization for disinfection.

Fifteen (15) kilograms of dried-weight soil were contained in each plastic pot. Recommended Nitrogen and Potassium fertilizer were incorporated into the soil basally. After potting, bags were laid out in the open field. Pots were placed in an individually dug pit with a 0.5m depth pit allowing a 5 cm portion of the pot exposed to the surface. It was done to simulate the normal soil temperature condition for rice production. Pots were saturated with water at a rate of five (5) liters per pot before seeding.

3. Planting of Seeds and Thinning-out of Test Plants

Before planting, seeds were sun-dried for 2-3 hours to activate the embryo. Ten (15) seeds with treatment were planted in each pot. 14 days after emergence, each pot was thinned out until one seedling remained.

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4. Fertilizer application

Before sowing, Nitrogen and K-based fertilizer (20-0-22) and other micronutrients were applied basally at a rate of 0.5 kg/plot.

N and K fertilizer's recommended rate were applied at split application; the first application was applied basally before planting and the second Split at 40 days from sowing. A top-dressing of 46-0-0 was done at panicle initiation. No addition of the P component was applied in the crop's entire growth stages after seed treatment.

5. Water management

Irrigation was maintained at field capacity for three days to enhance the development of seedlings. After that, intermittent watering or alternate wetting and drying method was done.

6. Pest management

Pest monitoring was done regularly early in the morning or late in the afternoon for proper management. Three pesticide sprayings were executed to control pests in the experimental field. Leaf blight disease, leafhoppers, rice bugs, and birds are the common pests observed in the area. Weed in the plots was regularly removed.

7. Harvesting

All test plants were harvested when formed grained already reached 80% maturity. Manual harvesting of grains was executed. Plant biomass (shoots, roots, and grains) was separately harvested for data gathering and evaluation. Grains were manually threshed, separately contained in mesh bags, and labeled appropriately. Seeds were sun-dried until they reached 14% moisture content (MC). Dried seeds were stored in mesh bags at room temperature, sorted, weighed, and evaluated.

8. Weather monitoring

Regular monitoring of weather changes such as rain events as well as temperature variations was noted. Simulation of the available real-time weather monitoring system and local weather data gathered at the end of the experimentation.

e. Data Gathered

1. Tillering Ability

The number of productive and unproductive tillers produced per plant was counted 60 -75 days from emergence (DAE) and when 50% 0f the spikelets already emerged.

2. Microbial density and zone of infection

About 10 g roots were sampled in the different growth stages (vegetative, Anthesis, grain-filling, and maturity) using destructive sampling. Sampling and collection followed the method of Niwa et al. (2018). Briefly, roots and root-zone soils (20 cm depth) collected from representative plants in each treatment replicate and combined. Roots gently washed with tap water. About 1 g subsamples (lateral roots) were collected, cut into 1 cm segments, and

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randomized in distilled water. Roots were blotted on a paper towel, cleared in 10% potassium hydroxide, and stained with Trypan blue before microscopy. The percentage of root length colonized by AMF is estimated by a modified line intersection method (McGonigle et al., 1990). Fifty (50) root units were examined for each treatment sample under stereo zoom binocular microscope for studying AM colonization, and the rate (%) of colonization was calculated as follow:

$$\text{AM colonization (\%)} = \frac{\text{Total number of root bits infected}}{\text{Total number of root bits examined}} \times 100$$

Total fungi determined using the microbial counting method specialized for determining Mycorrhizal population in soil developed by Ecosystems Research and Development Bureau (ERDB). Briefly, 50 g of soil sample was obtained from each treatment. The soil was suspended in 1000 ml of sterile distilled water and shaken for 1 minute on a rotary shaker. Afterwhich, the soil solution passed through a #325 and #100 sieve mesh and was washed with 50 mL water. The recovered water solution was centrifuged for ten minutes at 4000rpm. The centrifuged solution will be further washed in a sieve with 10 mL distilled water and recalibrate to 50mL with sucrose solution for final centrifugation. The final washing of propagules will be stored in a plate lined with customized lined filter paper. All the plates will be incubated at 37 °C for 3 to 5 days, and a count made to determine the number of spores developed.

3. P content in biomass and soil

For measuring total biomass and P concentration of root and shoot part, another set of plants harvested in each treatment, combined and dried at 80C for 72 hours. Plant samples were ground and weighed and sent out to an accredited laboratory for analysis. Soil samples were collected, air-dried for 72 hours, sealed in polypropylene bags, and brought to the laboratory for analysis.

4. P uptake per unit root length and per plant.

Phosphorus uptake followed the method of Gonzales (2004). P uptake rate is based on three sampling periods following phenological stage sampling of plants (vegetative, Anthesis, and grain-filling).

5. Yield and yield components

All grains developed from experimental plants harvested, dried at 14% moisture content, and weighed to determine yield obtained per treatment. The number of grains per panicle, weight per grain, and total mass of grains per plant was determined. The contribution of Mycorrhizae inoculation and P application by different application methods to yield was measured using the formula

Yield response to inoculation = (Yield in inoculated plant – mean yield in controlplant) / Mean yield in control plants

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Harvest index is calculated using the formula

$$\textbf{HI (\%) = (Economic Yield /Biological Yield) x 100}$$

f. Statistical Analysis

Gathered data were subjected to analysis of variance (ANOVA) using the statistical tool STAR and mean separation test using Least Significant Difference and Tukey's honest significant difference test (HSD) at a probability level of 5%.

3) RESULTS AND DISCUSSION

a. Tillering ability

The rice varieties' ability to produce productive tillers affected with seed treatment of M and different P levels was determined and presented in Table 1. The application of different P levels regardless of the seed treatment method and variety manifested a significant effect. The application of M with 50% of recommended P (P_4) and 100% P (P_5) increased the tillering ability of both rice varieties by 13.90-26.15% as compared with plants applied with 150% P (P_6), a single application of recommended P (P_2), Mycorrhizae sp. alone (P_3) and untreated plants (P_1).

Table 1. The number of productive tillers and percentage of productive tillers (%) as affected by seed treatments (Seed coating and Seed biopriming) of Mycorrhizae sp. and different P levels to two rice varieties and interaction effects.

Indivudual Factor Effect				
Treatment	**Productive tillers**			
	Number		**Percentage (%)**	
Factor A - Seed Treatment[1]				
S_1 - Seed Coating (SC)	21.982		58.360	
S_2-Seed biopriming (SBp)	22.543		58.438	
FACTOR B – Variety[2]				
V_1 - NSIC Rc 222	22.288		60.075	a
V_2 - NSIC Rc 480	22.238		58.940	b
FACTOR C - Phosphorus level[3]				
P_1 - No application (Control)	22.383	b	46.128	e
P_2 - Recommended P alone (RP)	20.538	b	57.418	c
P_3 - Mycorrhizae sp. alone (M)	21.683	b	62.466	b
P_4 - M+50% of RP	25.583	a	68.226	a
P_5 - M + 100% RP	23.110	ab	63.205	b
P_6 - M + 150% of RP	20.280	b	52.952	d
Comparison of seed treatment at each level of Variety and P levels +Mycorrhizae sp.				
Phosphorus levels	**Seed treatment**	**Productive tillers (%)**		

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		NSIC Rc 222		NSIC Rc 480	
P_1 -Control	S_1 - SC	47.135	a	46.245	a
	S_2-SBp	44.730	a	46.400	a
P_2 - RP	S_1 - SC	59.698	a	54.258	a
	S_2-SBp	58.845	a	56.873	a
P3 - M	S_1 - SC	68.563	a	58.843	a
	S_2-SBp	60.665	b	61.795	a
P4 - M+50% of RP	S_1 - SC	73.775	a	65.460	a
	S_2-SBp	65.205	b	68.465	a
P5 - M + 100% RP	S_1 - SC	65.170	a	59.180	a
	S_2-SBp	63.235	b	65.235	a
P6 - M + 150% of RP	S_1 - SC	58.948	a	43.053	b
	S_2-SBp	54.935	a	54.873	a

Comparison of variety at each level M and P

Treatment	Rice Variety	Productive tillers (%)			
		Seed Coating		Seed biopriming	
P_1 -Control	V_1	47.135	a	44.730	a
	V_2	46.245	a	46.400	a
P_2 - RP	V_1	59.698	a	58.845	a
	V_2	54.258	b	56.873	a
P3 - M	V_1	68.563	a	60.665	a
	V_2	58.843	b	61.795	a
P4 - M+50% of RP	V_1	73.775	a	65.205	a
	V_2	65.460	b	68.465	a
P5 - M + 100% RP	V_1	65.170	a	63.235	a
	V_2	59.180	b	65.235	a
P6 - M + 150% of RP	V_1	58.948	a	54.935	a
	V_2	43.053	b	54.873	a

. Comparison of Phosphorus levels at each level of seed treatment and variety

Seed Treatment	P Levels	Productive tillers (%)				
		Variety				
		V_1 - NSIC Rc 222			V_2 - NSIC Rc 480	
S_1 - Seed Coating (SC)	P_1 - No application (Control)	47.135	e		46.245	c
	P_2 - Recommended P alone (RP)	59.698	cd		54.258	b
	P_3 - Mycorrhizae sp. alone (M)	68.563	ab		58.843	b
	P_4 - M+50% of RP	73.775	ab		65.460	a
	P_5 - M + 100% RP	65.170	bc		59.180	b
	P_6 - M + 150% of RP	58.948	d		43.053	c
S_2-Seed biopriming (SBp)	P_1 - No application (Control)	44.730	d		46.400	e
	P_2 - Recommended P alone (RP)	58.845	bc		56.873	cd
	P_3 - Mycorrhizae sp. alone (M)	60.665	ab		61.795	bc
	P_4 - M+50% of RP	65.205	a		68.465	a
	P_5 - M + 100% RP	63.235	ab		65.235	ab

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	P_6 - M + 150% of RP	54.935	c		54.873	d
Means with the same letter are not significantly different at 0.05 level using [1]Least Significant Difference (LSD) and [2]Tukeys Honest Significant Difference (HSD)						

The number of productive tillers was defined by the individual factor effects and the three factors' interaction. NSIC Rc 222 gave a higher number of productive tillers than NSIC Rc 480. While the application of M+50% of RP gave the highest number of productive tillers with 68.226% of the number of tillers developed, followed by the application of M + 100% RP (63.205%), Mycorrhizae sp. alone (M) (62.466%), Recommended P alone (RP) (57.418%) and M + 150% of RP (52.952%) that significantly boost growth and development of plants compared with untreated ones. Reducing the P level to 50% of the recommended rate combined with Mycorrhizae sp. corresponds to 10.80% additional productive tillers compared with recommended P, 5.76% over those applied with Mycorrhizae sp. alone, and 22.10% increase over the untreated plants.

According to seed treatment applied, interaction effects revealed that S_1P_3, S_1P_4, and S_1P_5 initiated higher production of tillers ready for flowering for NSIC Rc 222 while the addition of 50-100% P with M or applied alone gave comparable tillering effects to NSIC Rc 480.

NSIC Rc 222 is more responsive to tillering when subjected to seed coating treatment at any P levels and Mycorrhizae sp. application, while seed bio priming gave a comparable response to all treated and untreated plants.

In terms of P levels, the introduction of M+50% of RP or Mycorrhizae sp. alone (M) through seed-coating during the early stage of plant development significantly enhanced tillering formation as well as the development of productive tillers of NSIC Rc 222 while the utilization of seed biopriming to introduce Mycorrhizae sp. alone (M), M+50% of RP and M + 100% RP to NSIC Rc 222 likely to develop a higher number of tillers per plant among other treatments as summarized in Table 1d. The same effect is observed for NSIC Rc 480, where M+50% of RP through seed coating and M+50% -100% RP boosted tillering.

b. Yield and yield components

1. Number of panicle and grains per panicle. The effect of two different seed treatments and various P levels and Mycorrhizae sp. was measured on the yield performance of two rice varieties, namely NSIC Rc 222 and NSIC Rc 480. The total number of panicles per hill, grain per panicle, and percentage filled grain obtained were summarized in Table 2. Results showed that plants inoculated with M+50% of RP produced the highest number of panicles per hill that is equally productive with M + 100% RP. Increasing the amount of P (M + 150% of RP) produced panicles comparable with applying M alone and P alone. Application of P alone manifested the same panicle count as that of the untreated plants. The interaction of seed coating and P levels gave the same effect on panicle formation.

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Table 2. The number of panicles per hill, the number of grain per panicle, and percentage filled grained obtained as affected by two seed treatments of Mycorrhizae sp. and different Phosphorus levels to two rice varieties.

TREATMENT		No. of panicle/ hill		Grain/ panicle		Percent (%)filled grain	
Factor A - Seed Treatment[1]							
	S_1 - Seed Coating (SC)	12.088		132.296		69.078	
	S_2-Seed biopriming (SBp)	13.093		140.808		69.251	
FACTOR B – Variety[1]							
	V_1 - NSIC Rc 222	13.024		156.792		69.074	
	V_2 - NSIC Rc 480	12.158		116.313		69.255	
FACTOR C - Phosphorus level[2]							
	P_1 - No application (Control)	9.489	d	124.988	b	63.736	de
	P_2 - Recommended P alone (RP)	10.987	cd	132.913	b	66.105	d
	P_3 - Mycorrhizae sp. alone (M)	12.481	bc	143.825	ab	73.321	b
	P_4 - M+50% of RP	16.027	a	155.400	ab	79.110	a
	P_5 - M + 100% RP	14.398	ab	135.425	ab	69.811	c
	P_6 - M + 150% of RP	12.162	c	126.763	b	62.904	e

The number of grains produced per panicle, M alone or combining M with 50-100% P markedly developed the highest number of grains per panicle. Reducing P levels and combined with M whether applied through seed coating or biopriming resulted in the same grain number recovery with the full use of recommended P with M, M alone, or P alone. Further, an increase in P level to 150% gave the same effect with P alone, M alone, and untreated plants regardless of variety.

The effect of P levels is evident in terms of the recovered filled grain per panicle. Plant efficiency to acquire nutrients in the soil is commonly measured with their ability to produce filled grains (Figure 2). Data revealed that M+50% of RP regardless of seed application method and various increased numbers of filled grain by 5.789% over P_3 - Mycorrhizae sp. alone (M), 9.299-13.005% higher than P_5 - M + 100% RP or recommended P alone (RP). While increasing P levels to 150% of the RP with M did not improve rice varieties' grain filling to control. Interaction of Phosphorus level and seed treatment showed remarkable differences in the maturity performance of the two rice varieties. M+50% of RP, whether applied through seed coating or bio priming, manifested higher filled grain recovery with 77.80-80.421% comparable with applying plants with Mycorrhizae sp. alone (M) M + 100% RP. Moreover, the reduction of P concentration to 50% with M combination showed a remarkable advantage of 9-13% and over recommended P alone (RP) and untreated plants applied using seed bio priming and 12.91-21.37% when seed coated.

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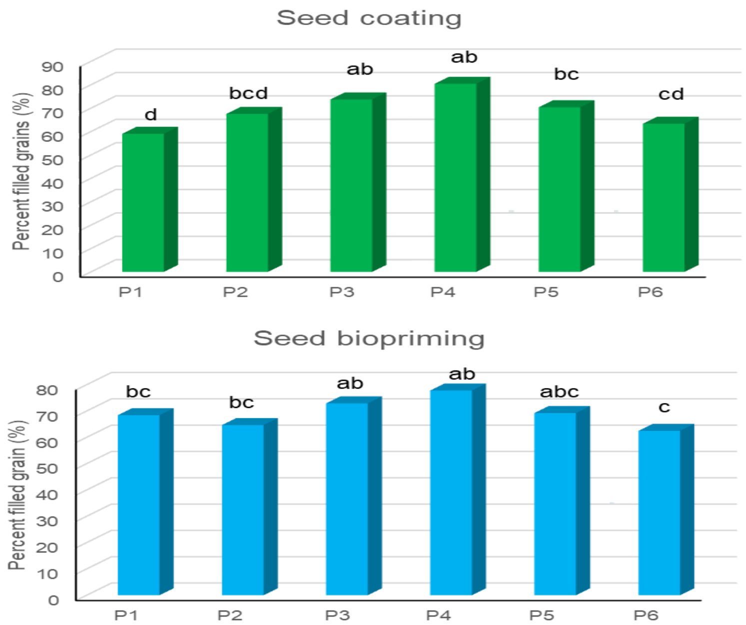
Figure 2: Percentage (%) filled grain recovered as affected by M and different Phosphorus levels at each level of seed treatment applied



2. Actual and estimated yield. In terms of grain weight, all the different treatments showed no differences in the individual effects of the different factors tested on the weight of 100 grains. The single effect of factors, seed bio priming produced a higher yield than seed coating. NSIC 222 gave a higher yield recovery than NSIC Rc 480 as reflected in Table 3. The yield parameter variation is evident in the average yield per hill and yield per square meter obtained from treatments. Plants subjected to M+50% of RP yielded the highest with a 37.494g/ hill recovery followed by P_5 - M + 100% RP with 30.036 g/hill. The combined P and M's yield performance markedly improved rice yield than applying M or P alone. Moreso, excessive addition of P up to 150% of the recommended usage resulted in reduced yield. The fertilizer intervention resulted in projected yield on the average of 7.499 tons/ ha when applied with Mycorrhizae sp. and 50% of recommended P concentration. Evidently, NSIC Rc 222 is projected to harvest 5.770 tons/ha which is markedly higher than NSIC Rc 480 with 4.307 tons/ha projection. The interaction effect of fertilizer and seed coating on rice varieties' weight manifested significant differences among treatment means. Seed-coated plants produced comparable grain weight for 100 grains true to all treatments applied and the control. Plants subjected to seed biopriming of Mycorrhizae sp. alone (M), M+50% of RP, M + 100% RP and M + 150% of RP showed equally heavy grains as of that Recommended P alone (RP) and significantly higher with the untreated plants.

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Table 3: The actual and projected yield of two rice varieties subjected to seed treatment of Mycorrhizae sp. and different levels of Phosphorus under P-deficient soil and comparison of interaction effects

Treatment	Weight of 100 grains (g)	Yield per hill (g/hill)		Yield /m^2 (g/ m^2)		Yield/ha (tons/ha)	
Factor A - Seed Treatment[1]							
S_1 - Seed Coating (SC)	2.077	23.845	b	476.905	b	4.769	b
S_2-Seed biopriming (SBp)	2.017	25.937	a	518.743	a	5.187	a
FACTOR B – Variety[1]							
V_1 - NSIC Rc 222	2.031	28.862	a	577.015	a	5.770	a
V_2 - NSIC Rc 480	1.970	21.534	b	430.671	b	4.307	b
FACTOR C - Phosphorus level[2]							
P_1 - No application (Control)	1.962	13.471	f	269.410	f	2.694	f
P_2 - Recommended P alone (RP)	2.073	23.959	d	479.177	d	4.792	d
P_3 - Mycorrhizae sp. alone (M)	2.042	26.627	c	532.534	c	5.325	c
P_4 - M+50% of RP	1.998	37.494	a	749.872	a	7.499	a
P_5 - M + 100% RP	2.078	30.036	b	600.710	b	6.007	b
P_6 - M + 150% of RP	2.128	17.762	e	355.241	e	3.552	e

Comparison of different P levels at each seed treatment as effected weight of 100 grains.

Treatment	Weight of 100 grains (g)			
	Seed Coating		Seed biopriming	
P_1 - No application (Control)	2.120		1.804	b
P_2 - Recommended P alone (RP)	2.047		2.099	a
P_3 - Mycorrhizae sp. alone (M)	2.053		2.031	ab
P_4 - M+50% of RP	2.030		1.966	ab
P_5 - M + 100% RP	2.094		2.062	a
P_6 - M + 150% of RP	2.117		2.139	a

Comparison of Seed treatment at each level of Variety and P levels + Mycorrhizae sp. (VP)

Treatment		Parameter											
Phosphorus levels	Seed treatment	Yield per hill (g/hill)				Yield /m^2 (g/ m^2)				Yield/ha (tons/ha)			
		NSIC Rc 222		NSIC Rc 480		NSIC Rc 222		NSIC Rc 480		NSIC Rc 222		NSIC Rc 480	
P_1 –Control	S_1 - SC	13.363	b	9.211	a	267.266	b	184.209	a	2.673	b	1.842	a
	S_2-SBp	21.154	a	10.154	a	423.083	a	203.084	a	4.231	a	2.031	a
P_2 – RP	S_1 - SC	25.661	b	21.254	a	513.220	b	425.082	a	5.132	b	4.251	a
	S_2-SBp	30.097	a	18.823	a	601.946	a	376.463	a	6.019	a	3.765	a
P3 – M	S_1 - SC	27.641	b	21.621	a	552.808	b	432.418	a	5.528	b	4.324	a
	S_2-SBp	34.533	a	22.713	a	690.662	a	454.248	a	6.907	a	4.542	a
P4 - M+50% of RP	S_1 - SC	45.095	a	33.005	a	901.890	a	660.103	a	9.019	a	6.601	a
	S_2-SBp	39.662	b	32.213	a	793.246	b	644.249	a	7.933	b	6.443	a
P5 - M + 100% RP	S_1 - SC	30.533	b	25.093	a	610.649	b	501.864	a	6.107	b	5.019	a
	S_2-SBp	37.142	a	27.375	a	742.838	a	547.491	a	7.429	a	5.475	a
P6 - M + 150% of RP	S_1 - SC	21.873	a	11.795	b	437.462	a	235.893	b	4.375	a	2.359	b
	S_2-SBp	19.456	a	17.925	a	389.113	a	358.495	a	3.891	a	3.585	a

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Comparison of variety at each level of seed treatment and P levels + Mycorrhizae sp. (SP)

Treatment		Parameter											
Phosphorus levels	Variety	Yield per hill (g/hill)				Yield /m² (g/ m²)				Yield/ha (tons/ha)			
		Seed Coating		Seed biopriming		Seed Coating		Seed biopriming		Seed Coating		Seed biopriming	
P1 –Control	V1	13.363	a	21.154	a	267.266	a	423.083	a	2.673	a	4.231	a
	V2	9.211	b	10.154	b	184.209	b	203.084	b	1.842	b	2.031	b
P2 – RP	V1	25.661	a	30.097	a	513.220	a	601.946	a	5.132	a	6.019	a
	V2	21.254	b	18.823	b	425.082	b	376.463	b	4.251	b	3.765	b
P3 – M	V1	27.641	a	34.533	a	552.808	a	690.662	a	5.528	a	6.907	a
	V2	21.621	b	22.713	b	432.418	b	454.248	b	4.324	b	4.542	b
P4 - M+50% of RP	V1	45.095	a	39.662	a	901.890	a	793.246	a	9.019	a	7.933	a
	V2	33.005	b	32.213	b	660.103	b	644.249	b	6.601	b	6.443	b
P5 - M + 100% RP	V1	30.533	a	37.142	a	610.649	a	742.838	a	6.107	a	7.429	a
	V2	25.093	b	27.375	b	501.864	b	547.491	b	5.019	b	5.475	b
P6 - M + 150% of RP	V1	21.873	a	19.456	a	437.462	a	389.113	a	4.375	a	3.891	a
	V2	11.795	b	17.925	a	235.893	b	358.495	a	2.359	b	3.585	a

Comparison of Phosphorus levels + Mycorrhizae sp. at each level of coating and variety (PSV)

Seed Treatment	P Levels	Yield											
		g/hill)				g/ m²				Projected tons/ha			
		Variety				Variety				Variety			
		V1 - NSIC Rc 222		V2 - NSIC Rc 480		V1 - NSIC Rc 222		V2 - NSIC Rc 480		V1 - NSIC Rc 222		V2 - NSIC Rc 480	
S1 - Seed Coating (SC)	P1	13.363	e	9.211	d	267.266	e	184.209	d	2.673	e	1.842	d
	P2	25.661	cd	21.254	c	513.220	cd	425.082	c	5.132	cd	4.251	c
	P3	27.641	bc	21.621	bc	552.808	bc	432.418	bc	5.528	bc	4.324	bc
	P4	45.095	a	33.005	a	901.890	a	660.103	a	9.019	a	6.601	a
	P5	30.533	b	25.093	b	610.649	b	501.864	b	6.107	bc	5.019	bc
	P6	21.873	d	11.795	d	437.462	d	235.893	d	4.375	d	2.359	d
S2-Seed biopriming (SBp)	P1	21.154	d	10.154	e	423.083	d	203.084	e	4.231	d	2.031	e
	P2	30.097	c	18.823	d	601.946	c	376.463	d	6.019	c	3.765	d
	P3	34.662	b	22.713	c	690.662	b	454.248	c	6.907	b	4.542	c
	P4	39.662	a	32.213	a	793.246	a	644.249	a	7.933	a	6.443	a
	P5	37.142	ab	27.375	b	742.838	ab	547.491	b	7.429	ab	5.475	b
	P6	19.456	d	17.925	d	389.113	d	358.495	d	3.891	d	3.585	d

Means with the same letter are not significantly different at 0.05 level using [1]Least Significant Difference (LSD) and [2]Tukeys Honest Significant Difference (HSD)

Interaction effects in terms of seed treatment applied to P levels and variety showed that applying different P levels by seed biopriming enhanced NSIC Rc 222 and NSIC 480 except M+50% RP. The seed-coating of M+50% of RP to rice plants improved plant yield in NSIC 222 by 5.433 g/hill over the seed biopriming technique. The yield due to reduced application of P+M through seed coating can be estimated advantage of 108.644g/m^2 or a projected added yield of 1.086 tons/ha compared to seed biopriming. A comparison of the two varieties at each level of P and seed treatment revealed that NSIC Rc 222 gave a higher yield than NSIC Rc 480 accurate to all P levels and seed treatment. The interaction effect of PxSxV is showed that seed coated rice varieties with M+50% of RP increased yield b by three to four-fold higher than the

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untreated plants/hill and doubled compared to P alone. While M+50% of RP showed comparable yield/hill with M + 100% RP, but significantly higher than P_2 and P_3. Moreso, M+50% of RP seed-coated to NSIC Rc 222 and 480 remarkably greater than obtained through seed biopriming of same P level.

An increase in yield is associated with the application of P levels. Utilization of 50% of the recommended P seed-coated or bio primed to plants resulted in 742.838 – 901.890g/m^2 for NSIC Rc 222 and 547.491-660.103g/m2 for NSIC Rc 480. The projected yield obtained as effected to 50% P application through seed coating to NSIC Rc 222 revealed 1.8tons advantage over M + 100% RP and M alone while 3.9 tons/ha, 4.7tons/ha, and 6.4 tons/ha higher than RP alone (RP), M + 150% of RP and untreated control, respectively. The seed bio priming of M+50% of RP and M + 100% RP affected 1-1.5 ton/ha increases over RP alone (RP) and M alone. Further increasing P levels to 150% of RP resulted in a reduced 3.891ton/ha yield compared to untreated control. The yield obtained from both varieties is within the plants' maximum yield limits when planted under irrigated or rain-fed conditions. The two varieties applied with M+50% of RP through seed coating in lahar-laden soil or P-deficient soils increased yield than the recommended fertilizer regime. In terms of Harvest Index (HI), biopriming of seeds regardless of variety and P levels resulted in higher HI than Seed coated ones. While NSIC Rc 222 manifested a higher HI of 0.182 than NSIC Rc 480. P levels' individual effects revealed that M+50% of RP application gave the highest HI among all treatments and the control. The increased yield may be attributed to the increased number of productive tillers observed, root formation, P uptake, and microbial contribution (Table 4). Interaction of PSV revealed that application of M+50% of RP through seed coating and M+50% of RP and M + 100% RP by biopriming in both rice varieties improved harvest index compared to Recommended P alone (RP), Mycorrhizae sp. alone (M) and M + 150% of RP. Nevertheless, seed-coated plants with 50% P concentration showed outstanding HI among all treatments applied to both varieties

Table 4. Harvest Index of two rice varieties seeds treated with different levels of Phosphorus and Mycorrhizae sp.

Treatment		Harvest index (HI)	
Factor A - Seed Treatment[1]			
	S_1 - Seed Coating (SC)	0.158	b
	S_2-Seed biopriming (SBp)	0.171	a
FACTOR B – Variety[1]			
	V_1 - NSIC Rc 222	0.182	a
	V_2 - NSIC Rc 480	0.146	b
FACTOR C - Phosphorus level[2]			
	P_1 - No application (Control)	0.071	f
	P_2 - Recommended P alone (RP)	0.161	d
	P_3 - Mycorrhizae sp. alone (M)	0.173	c
	P_4 - M+50% of RP	0.222	a
	P_5 - M + 100% RP	0.193	b
	P_6 - M + 150% of RP	0.129	e

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Comparison of Phosphorus levels + Mycorrhizae sp. at each level of coating and variety (PSV)

Seed Treatment	P Levels	Harvest index (HI)			
		Variety			
		V_1 - NSIC Rc 222		V_2 - NSIC Rc 480	
S_1 - Seed Coating (SC)	P_1 - No application (Control)	0.103	c	0.077	c
	P_2 - Recommended P alone (RP)	0.181	b	0.161	b
	P_3 - Mycorrhizae sp. alone (M)	0.158	b	0.152	b
	P_4 - M+50% of RP	0.237	a	0.224	a
	P_5 - M + 100% RP	0.174	b	0.183	b
	P_6 - M + 150% of RP	0.159	b	0.085	c
S_2-Seed biopriming (SBp)	P_1 - No application (Control)	0.170	b	0.086	e
	P_2 - Recommended P alone (RP)	0.182	b	0.120	d
	P_3 - Mycorrhizae sp. alone (M)	0.226	a	0.155	bc
	P_4 - M+50% of RP	0.233	a	0.195	a
	P_5 - M + 100% RP	0.231	a	0.185	ab
	P_6 - M + 150% of RP	0.136	c	0.137	cd
Means with the same letter are not significantly different at 0.05 level using Tukey's Honest significant difference test (HSD)					

2. Phosphorus and Mycorrhizae sp. Contribution to Yield Improvement.

The increase in yield can be associated with the P uptake and Mycorrhizae sp. contribution to nutrient uptake. The yield response to microbial inoculation (yield difference over the control) is presented in Table 5. Data noted that Mycorrhizae sp. contribution to plant reproductive performance was highest when added with 50% P and introduced to plants through seed coating or seed biopriming with comparative performance to applying Mycorrhizae sp. alone. Similarly, Mycorrhizae sp. contribution to yield gradually reduced when combined with 100% RP and negative yield impact with further P increase to the rice varieties tested compared to inoculated M plants and the control.

The contribution of reduced P blended with M and introduced at the early stage of plant growth initiated the profuse formation of very fine roots responsible for increasing plants' nutrient uptake. Under P-deficient soil, the Mycorrhizae sp. Population increased at limited P, resulting in more fine roots for nutrient uptake. It was observed that under normal conditions, the two rice varieties' root systems developed more lateral roots than fine roots. When P concentration increased, both formations of lateral and fine roots are temporarily suspended until the plant reached the post-tillering to reproductive period. The formation of lateral and fine roots may have affected the plant's ability to uptake nutrients for growth and reproductive purposes.

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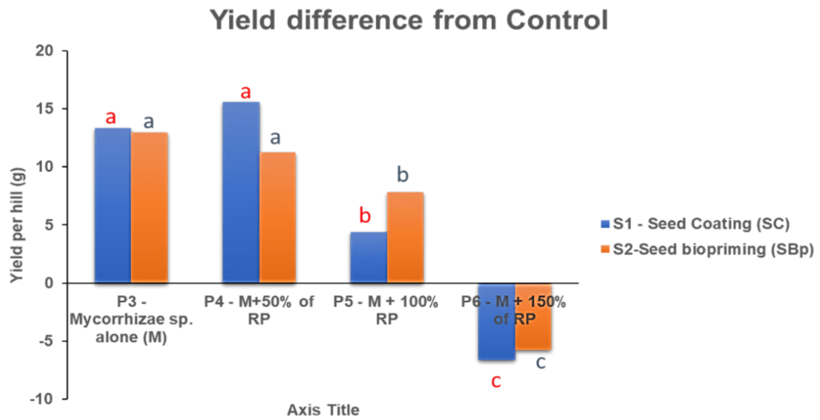
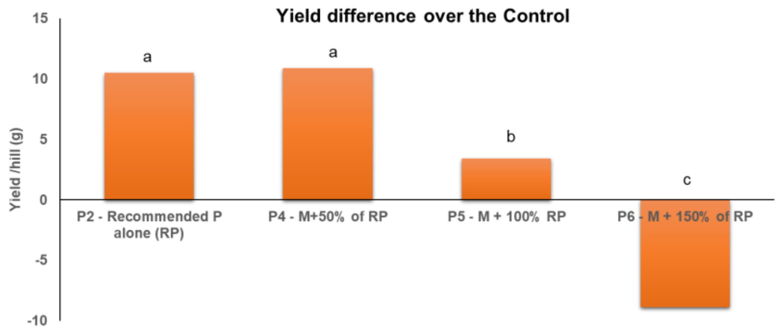


Figure 3. Contribution of Mycorrhizae sp. to yield (g/hill) of rice subjected to seed treatment of different levels of Phosphorus and Mycorrhizae sp

In terms of yield response to P levels, the addition of 50% P with the recommended rate of Mycorrhizae sp. increased plant yield with comparable output with applying P alone. Gradual impact on yield is associated with the application of 100% RP while inhibition effect was observed when the P level is further increased from the recommended rate regardless of the type of seed treatment used and varieties tested (Figure 3).

Figure 4.Yield difference of rice varieties as response to P level application



From the study's findings, seed treatment contributed to the early availability of nutrients to the root zone. However, the rate of absorption cannot be directly associated with the amount of P applied but with the plant's ability to take up Phosphorus. The finding is supported with Watts-Williams and his co-worker's (2015) works that plants' ability to take up P from soil depends on the root morphology of plants and can be modified using microbes such as Mycorrhizae sp. In this experiment, the introduction of Mycorrhizae sp. with as seed coat or bioprimed increased the rate of P uptake of both rice varieties, which is evident through root elongation at the early to the pre-flowering stage. Moreso, the combination of P+M applied in a reduced level, or recommended dosage showed significant uptake of P concentration in roots during the growing period and subsequently increased accumulation in the shoots to support flowering and maturity requirements. This result conforms to several researchers' works that P

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concentration in the shoots and roots of mycorrhizal plants can be significantly higher than in non-mycorrhizal plants grown under soil P deficiency (Ning&Cumming, 2001; Tawaraya et al., 2012). P concentration was reported to reduce plant performance in tillering ability, root formation, R/S ratio, and even yield performance. According to some researchers, high levels of P input showed to decrease colonization of arbuscular Mycorrhizae sp. fungus as well as the abundance and richness of the fungi in the roots and the soil (Olsson et al., 1997; Camenzind et al., 2014; Chen et al., 2014). Frew cited that most plants associate with arbuscular mycorrhizal (AM) fungi, enhancing their growth and nutrient uptake. The AM symbiosis outcomes can be highly variable, depending on soil fertility, plant functional group (C_3, C_4), and AM fungal diversity. Phosphorus (P) is a crucial nutrient for plant growth, but its availability to roots is limited in soil. Arbuscular mycorrhizal (AM) symbiosis is a promising strategy for improving plant P acquisition. However, P fertilizer reduces fungal colonization (P inhibition) and compromises mycorrhizal P uptake, warranting studies on P inhibition's mechanistic basis. In this study, microbial density decreased with an increase in P levels beyond the recommended rate. The number of infected propagules in 150% P decreased, which manifested inhibition of infection. Subsequently, microbial spores are present in the soil, but maybe its development and infection were temporarily inhibited in roots due to high P levels that conform to Kobae and his co-workers (2016). The result of this finding is important in the rehabilitation of the lahar-laden soils of the region especially to rice producing areas. More so, this result is not limited to one condition but it is of significant importance to Phosphorus-limited areas engaged into rice production. With the current market situation, the use of the microbial technology through the technique used may be helpful in reducing the synthetic fertilizer use of farmers while maintaining the quality and quantity of their harvest. The ecological soundness of the use of the microbes complementing the limited use of synthetic fertilizer further foreseen sustainable and ecologically sound.

Economics of the Technology

The economic advantage of using the technology is shown in Table 5. The partial budget analysis reflected that the use of combination of M with 50% of the recommended P resulted to 44.92% increase in income compared to using Phosphorus alone and 38.11% increase than using Mycorrhizae alone. The application of the microbes to increasing synthetic fertilizer resulted to declining yield that may be an additional expense for the farmer.

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Table 5: Partial budget analysis of rice production under P-limited condition when applied with Mycorrhizae sp and different P levels using seed treatment

Parameter	No P Application	Phosphorus only	Mycorrhizae only	50% RP+M	100%RP+M	150%RP+M
Yield (ton/ha)	2.69	4.79	5.38	7.50	6.01	3.55
Projected Sale (Php)	40,410.00	71,880.00	80,625.00	112,485.00	90,105.00	53,280.00
Added Cost	-	3,181.85	1,200.00	2,790.93	4,381.85	5,972.78
Total income	**40,410.00**	**68,698.15**	**79,425.00**	**109,694.08**	**85,723.15**	**47,307.23**
Added Returns	0	**28,288.15[a]**	**39,015.00[a]**	**40,995.93***	**17,025.00***	**(21,390.93)***
				30,269.08**	**6,298.15****	**(32,117.78)****
Assumptions Price of palay : Php15.00/kg; Cost of Phosphorus fertilizer per kg: Php 17.50; Recommended P requirement/ha: 181.82 kg; Recommended Mycorrhizae sp./ha : 15kg; Cost per 300 g inoculant: Php 80.00						
Note: [a]Compared to contro;l*Compared with P alone; **Compared with M alone						

4) CONCLUSION

1. Seed coating and seed biopriming of 50-100% of recommended P combined with Mycorrhizae enhanced yield performance of two rice varieties that resulted in a 3-4-fold increase in yield compared to P alone M alone and the untreated plants.
2. Application of Mycorrhizae with 50-100% P improves yield in terms of the number of panicles per hill, weight of grains, yield per hill, yield per hectare, and harvest index when applied as a seed coating. The addition of 50% P with a recommended rate of Mycorrhizae increased plant yield with comparable output with applying P alone.
3. Combining Mychorrhizae as seed treatment with 50% P incurred 38.11 to 44.92% increase in income of farmers. Further addition synthetic fertilizer combined with microbes limit the yield of rice under lahar-laden P-limited soil.

5) RECOMMENDATION

Based on the research finding, it is recommended that seed coating or seed biopriming of 50% P with Mycorrhizae to NSIC Rc 222 or NSIC Rc 480, respectively, is advantageous to planting in enhancing root formation, nutrient uptake, and growth performance of plants that will give remarkable advantage to yield. Moreso, this study is only limited to predicting AM fungi and P fertilizer's performance under P-deficient soil conditions; hence, it is recommended that the result be further verified to normal field conditions both in the wet-dry seasons for different rice varieties.

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