Evaluating the Impact of Phosphate-Solubilizing Mycorrhiza Biofertilizer Vs Urea Fertilizer on Paddy Growth

Gianlucca Vially Anak Ambu., Hamizah Othman*

Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA Melaka Kampus Jasin, Malaysia

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ABSTRACT

Use efficiency and environmental pollution caused by conventional urea fertilizer have given rise to the interest in the use of phosphate-solubilizing mycorrhiza (PSM) biofertilizer as an alternative to the conventional fertilizer to improve rice productivity which depends heavily on its availability of nitrogen and phosphorus. This study investigated the growth performance of paddy with PSM biofertilizer, urea fertilizer and their combination application. The experiment was carried out at the Universiti Teknologi MARA (UiTM) Cawangan Melaka under greenhouse condition with Completely Randomized Design (CRD) with 4 treatments consisting of T0 (control), T1 (PSM biofertilizer), T2 (urea fertilizer), and T3 (50% PSM biofertilizer + 50% urea fertilizer), each having 4 replications. At 60 and 75 days after sowing (DAS), the plant height, plant width, plant length and dry biomass were measured. The tallest plants in both the plant and plant biomass at 60 DAS (80.16 cm) and 75 DAS (100.20 cm) were obtained from integrated treatment (T3) whereas urea alone (T2) induced maximum biomass at 60 DAS (41.44 g). The most sustained nutrient supply over time is exhibited by T3 with the highest biomass at 75 DAS (40.59 g). PSM biofertilizer was applied alone (T1) which resulted in an increase in stem width compared with the control but did not perform as well as when combined with other treatments in overall growth. One-way ANOVA did not detect any statistically significant differences between treatments ($p>0.05$), however there were recognizable trends that were consistently in favour of producing a combined application. From these findings, it is suggested that for sustainable growth of paddy, the integrated nutrient management approach (use of PSM Biofertilizer with reduction of urea input) is a promising approach that will reduce the use of synthetic fertilizer.

Keywords: Paddy, Phosphate-Solubilizing Mycorrhiza Biofertilizer, Urea Fertilizer, Yield, Sustainable Agriculture

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the more widely cultivated crops in Asia, which is critical for food security of the region, and where N and P are important limiting factors for growth and productivity. Volatilization and leaching losses are the major limitations in the use of urea as the nitrogen source in paddy fields given its high nutrient content and quick release. Phosphorus has a high tendency to fixation in both acidic and alkaline soils and only 10–20% of the phosphorus applied is plant-available, resulting in high dependence on synthetic inputs.

This excessive use of chemical fertilizers, therefore, causes environmental degradation and rising production costs in conventional paddy cultivation. In contrast, biofertilizers containing arbuscular mycorrhizal fungi (AMF) and phosphate-solubilizing microorganisms (PSM) can enhance nutrient bio-availability and ability of the roots to uptake these nutrients which is more sustainable in soil fertility.

Phosphorus is not a limiting nutrient in the soil for PSM and AMF because both inoculants transform fixed phosphorus into soluble phosphorus, increasing the root exploration area through the network of hyphae. The objectives of this study are set as follows to assess the vegetative growth performance of paddy in the integrated nutrient management (INM); and to study the synergism efficiency of AMF and PSM inoculants along with reduced input of chemical fertilizers. Despite its high environmental cost and low nutrient use efficiency, many

growers still apply it at high rates, assuming that it will always give good yields, and uptake of biofertilizers continues to be low due to variable performance in the field and low farmer awareness.

This difference contributed to the present study to assess the growth performance of paddy grown with PSM biofertilizer, urea fertilizer, and their mixture (50:50) and to find out if the integrated nutrient management (INM) could be as productive as conventional nutrient management (CM) with urea fertilizer and is able to decrease the dependency on chemical fertilizer.

LITERATURE REVIEW

Phosphorus is an essential macronutrient involved in energy transfer, photosynthesis, and metabolic regulation, yet it remains highly immobile in many soils due to strong binding to soil minerals. Most soluble P in the soil solution constitutes a small fraction of total soil P, and plants primarily absorb orthophosphate ions (H^2PO^{4-} and $HPO^{4\hat{}2}$) that are transient in the soil solution. This causes a persistent potential for P deficiency in many cropping environments unless mobilized by biological or chemical processes (Sharma et al., 2022, Bhardwaj et al., 2014, Khan et al., 2023).

In rice systems, fixation of P can be especially problematic under acidic or alkaline soils, making inoculation-based mobilization strategies particularly impactful (Goutami, 2024, Bhardwaj et al., 2014). The general physics and chemistry of P fixation underscore the necessity of P-solubilizing strategies to enhance plant uptake and yield potential (Sharma et al., 2022, Bhardwaj et al., 2014, Debnath et al., 2020). Fertilizer quality, and crop stage can maximize growth benefits while maintaining cost-effectiveness.

PSB produce organic acids and phosphatases that solubilize insoluble phosphate, increasing P availability to rice roots and enhancing P uptake and biomass accumulation in rice under P-limited conditions (Wahid et al., 2022). Integrated with AMF, phosphorus mobilization can be further enhanced via mycorrhizal networks that extend root exploration and transfer P to the plant, particularly under flooded paddy conditions where AMF–plant associations are beneficial (Wahid et al., 2022, Reddy, 2024, Oladele et al., 2019).

Biofertilizers (including PSB and AMF) contribute to soil microbial activity, nutrient cycling, and organic matter dynamics, which can enhance nutrient-use efficiency and resilience to abiotic stress, potentially reducing long-term fertilizer requirements in paddy systems (Marzouk et al., 2025).

PSB solubilize inorganic phosphate, releasing P for uptake, which can boost growth and grain yield, particularly under P-limited soils. Paired with AMF, the P acquisition is enhanced via hyphal networks, potentially supporting higher yields or allowing reductions in P fertilizer inputs (Wahid et al., 2022). Examples in the rice study show increased P uptake and improved growth with PSB inoculations; AMF inoculation alone or in combination with PSB often shows enhanced root colonization and nutrient acquisition that correlate with improved growth metrics in paddy fields (Goutami, 2024).

METHODOLOGY

The experiment was conducted in greenhouse at Universiti Teknologi MARA (UiTM), Kampus Jasin in a pot trial based on Completely Randomized Design (CRD) with four treatments and four replications.

Table 1: Treatments and Details

Treatments	Details
T0	Control (No fertilizer/No inoculant).
T1	100% Recommended Rate of Nitrogen (RRN) via urea.
T2	Bio-Inoculant alone (AMF + PSM).
T3	Integrated (50% Urea + AMF + PSM).

Standardized paddy soil (Oxisols/Ultisols) was employed and the pre-planting composite soil analysis for total N, available P, exchangeable K and pH was done. Urea (46% N) was applied twice in the 2 split applications recommended by the Department of Agriculture, and AMF spores and PSM inoculant was applied as a soil drench at the time of transplanting.

The height, width, length and dry biomass (oven drying method) of the plants were measured at 60 and 75 days after sowing (DAS). Weeding was done manually to prevent disturbance of AMF colonization; water level was kept at 3–5 cm during vegetative stage and alternate wetting and drying was done at the reproductive stage. One-way ANOVA and Tukey's post hoc tests were used to analyse all data, at $\alpha = 0.05$.

RESULT AND DISCUSSION

The plants grown with combined treatment (T3) (80.16 cm at 60 DAS and 100.20 cm at 75 DAS) were found to be the tallest followed by urea alone (T2) (77.26 cm at 60 DAS and 89.32 cm at 75 DAS), while PSM biofertilizer alone (T1) (74.12 cm at 60 DAS and 85.50 cm at 75 DAS) provided the least height (Table 2). The results indicate that use of biofertilizer along with urea fertilizer could give better growth of paddy than application of either of fertilizer alone as it is expected to improve nutrient availability and uptake. If the T3 treatment always results in taller plants with a consistent superiority and statistically stands out, then the T3 treatment may be recommended to promote vegetative vigor, thereby improving photosynthetic activity and early biomass. But taller plants don't necessarily mean greater grain yield as there are other factors such as lodging risk, panicle architecture, and assimilate partitioning. A strategy of 50% PSMB and 50% urea might provide better nutrient use efficiency by using microbial nutrient release to increase nutrient release and decrease chemical nitrogen input compared with full rate urea strategies.

Table 2: Mean Plant Height (cm) at 60 and 75 Days After Sowing (DAS)

Treatment	60 DAS	75 DAS
T0 (Control)	78.74	95.90
T1 (PSM biofertilizer)	76.28	92.20
T2 (Urea fertilizer)	79.48	97.62
T3 (PSM + Urea, 50:50)	80.16	100.20

Dry biomass production increased with urea (T2) and the integrated application of P (via PSM/AMF) and N (via urea) (T3) increased at 60 DAS (41.44 g) and 75 DAS (40.59 g), respectively, due to the ability of nitrogen to promote early chlorophyll production, cell division, and sustained nutrient availability over longer periods. No significant difference was found between any treatments at the two sampling times for plant heights, width, length or biomass as determined by a one-way ANOVA ($p < 0.05$), and the Tukey test listed all treatments in one homogeneous group. This low significance is probably due to the limited number of plants ($n = 4$ per treatment) and the buffered greenhouse environment which causes a low level of nutrient stress between treatments. However, the persistent numerical superiority of T3 is consistent with other reports showing that AMF colonization can affect N uptake efficiency and improve shoot growth when used in conjunction with moderate mineral fertilization, and that reduced N inputs along with AMF can maintain yield but decrease the use of synthetic fertilizers in rice cropping systems.

CONCLUSIONS

The growth response of paddy plants under all the treatments (PSM, urea and PSM+ urea) was different with respect to the different growth parameters and sampling period. The PSM biofertilizer alone promoted the growth of the width of stems, presumably because of better phosphorus assimilation, while urea alone promoted biomass accumulation possibly because of the quick availability of nitrogen. Importantly, chemical treatment combined

with biological inoculants (T3) always had the best plant growth and total biomass after 75 DAS, suggesting a synergistic effect between biological inoculants and chemical treatments.

Within the limits of this controlled greenhouse experiment the observed trends are sufficient to strongly indicate that the use of PSM biofertilizer in combination with reduced application rate of nitrogen fertilizer is a very feasible alternative. This holistic nutrient management approach would sustain productivity of paddy crops while significantly lower reliance on synthetic N-fertilizers. In addition, this method can reduce the amount of excessive chemical runoff that can harm the environment. But these promising trends should be reproduced in more extensive multi-location field trials to fully substantiate them. A further investigation into the exact nutrient-use efficiency, cost-effectiveness, and impact on long-term soil health resulting from this synergistic integration are parameters that should be investigated in the future.

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