**Effect of new biofertilizer formulations on the growth and yield of rice (*Oryza sativa* L., var. VDG1) under field conditions**

**ABSTRACT**

This study aims to evaluate the agronomic efficacy of different formulations of RhizoMyx Eco Gr, a granular microbial bioformulation, on growth, yield attributes, and soil biological activity in paddy (*Oryza sativa* L., var. VDG1) under field conditions. The experiment was conducted from July 2024 to December 2024, covering a total duration of six months. The experiment was laid out in a Randomized Complete Block Design with 4 treatments, which included different levels of RhizoMyx Eco Gr formulations replicated four times with uniform agronomic practices. RhizoMyx Eco Gr-2 is a microbial bioformulation developed by Novozymes South Asia, and the main purpose of applying RhizoMyx Eco Gr-2 is to improve soil microbial activity and plant nutrition, ultimately sustainably enhancing crop productivity. The best treatment, RhizoMyx Eco Gr-2, significantly improved key growth and yield parameters of paddy variety VDG1 compared to the control (RhizoMyx Eco Gr-1 (Control), T1). Plant height increased by approximately 69% (from 21.28 cm to 35.95 cm), grain yield increased by 21.6% (from 5980 kg/ha to 7270 kg/ha), and straw yield improved by 24.7% (from 9390 kg/ha to 11710 kg/ha). Additionally, the vigour score increased by 6.7% (from 3.75 to 4.00). These enhancements are supported by higher tiller counts and improved nutrient uptake, demonstrating RhizoMyx Eco Gr-2 as the most effective biofertilizer treatment for enhancing paddy growth and productivity under the study conditions. These findings confirmed that RhizoMyx Eco Gr is a promising plant growth-promoting bio-input that enhances nutrient uptake and yield in rice.

*Keywords: Paddy, Rhizomyx Eco Gr Formulations, Plant growth parameters, Yield.*

**1. INTRODUCTION**

Rice is India's most important crop as it is the major source of sustenance for a substantial section of the country's population and preserves the lives of millions of people living in rural regions (Mohidem et al., 2022). Due to the continual expansion in the population, there is an increasing need for rice. It is of the highest significance to boost productivity, particularly when the amount of land that is accessible for rice cultivation is diminishing (Mallareddyetal., 2023). Rice is the second most extensively cultivated cereal crop after wheat and serves as the primary dietary staple food for over half of the global population. India is currently the world’s leading rice producer, with an estimated 51 million hectares under cultivation, producing about 225 million tonnes of rice in 2024–25, and achieving an average productivity of 4.41 tonnes per hectare (USDA, 2024). Major rice-producing states include West Bengal, Uttar Pradesh, Punjab, Andhra Pradesh, and Tamil Nadu, with Punjab having the highest productivity due to assured irrigation and input-intensive farming (DAC&FW, 2023). However, several concerns threaten the sustainability of rice production in India. These include stagnating yields, declining groundwater levels due to over-extraction (especially in Punjab and Haryana), high methane emissions from continuously flooded paddy fields, and environmental pollution caused by residue burning (ICAR, 2023; CPCB, 2022). Current rice agriculture is hindered by declining yields, water scarcity, excessive use of agrochemicals leading to natural resource degradation, biodiversity loss, and heightened greenhouse gas emissions, alongside increasing losses from extreme weather events (John and Ray, 2023). Nutrient management through bio-fertilizers is gaining importance as a sustainable alternative to chemical fertilizers, helping improve soil fertility, nutrient availability, and crop productivity while reducing environmental harm (Bhardwaj et al., 2014). Bio-fertilizers such as nitrogen-fixing and phosphate-solubilizing microorganisms enhance nutrient cycling and plant growth through eco-friendly mechanisms (Vessey, 2003). Selecting this approach is crucial for sustainable rice cultivation under current soil health and environmental challenges. One promising strategy is the application of biofertilizers that harness the benefits of beneficial rhizospheric microbes such as arbuscular mycorrhizal fungi (AMF) and plant growth-promoting bacteria (PGPB), in conjunction with organic amendments and nitrogen-fixing green manures like *Azolla* and leguminous cover crops (Ahmadi et al., 2014). Arbuscular mycorrhizal (AM) symbiosis, formed by fungi of the phylum Glomeromycota, enhances plant access to nutrients especially phosphorus and nitrogen through an expansive mycelial network, while receiving photosynthates from the plant in return. The evolutionary persistence of this symbiosis over more than 600 million years underscores its fundamental ecological role in plant nutrition, soil structure modulation, and stress mitigation under various edaphic and climatic conditions (Piliarová et al., 2019). Biofertilizers like RhizoMyco and RhizoMyx are built on this principle. RhizoMyco, containing 18 species of endo- and ectomycorrhizal fungi and growth-promoting agents, is available in soluble and injectable forms to boost nutrient availability and root architecture. RhizoMyx, an endomycorrhizal inoculant, enhances root nodulation and nutrient absorption, contributing to improved plant vigour and resilience (Yashavantha Rao et al*.*, 2020).

RhizoMyx Gr Formulation is developed by M/s.Novozymes South Asia Pvt.Ltd., Bangalore to evaluate this formulation in Paddy field at different treatments. This formulation comprises beneficial microbial consortia that are instrumental in improving soil fertility, increasing nutrient availability, and stimulating plant growth. Distinct from traditional chemical fertilizers, Rhizomyx Eco GR seeks to harness the natural symbiotic relationships between microbes and plants, thereby fostering sustainable agricultural practices and minimizing the environmental impact associated with conventional rice farming.

The objectives of the study are to evaluate the effect of RhizoMyx Eco Gr products on the biometric parameters of paddy and to assess their impact on the growth and yield parameters of paddy, particularly the variety VDG1. This investigation involves determining how different formulations influence plant vigour, height, tiller count, seed test weight, grain and straw yield, and overall crop productivity, thereby validating the efficacy of these microbial inoculants as environmentally friendly and cost-effective inputs for rice cultivation

**2. MATERIALS AND METHODS**

**2.1 Site description, experimental design, and treatment**

Field experiments were conducted at Sugarcane Research Station, Melalathur, Tamilnadu from July 2024 to December 2024, covering a total duration of six months with Lower Left 12.921969 Latitude (°N) 78.875595 Longitude (°E), Upper Left 12.922641 Latitude (°N) 78.875551 Longitude (°E), Upper Right 12.922823 Latitude (°N) 78.875505 Longitude (°E), Lower Right 12.922969 Latitude (°N) 78.875460 Longitude (°E) with temperature of 35°C to 41°C, Relative humidity percentages hovered between 75% and 94%,

The experimental site soil was characterized as sandy clay in texture, exhibiting slightly alkaline pH of 7.2 and the organic matter, available nitrogen(N), available phosphorous(P), available potassium (K) of the paddy soil were 0.5%, 173 kg ha-1, 18 kg ha-1, 215 kg ha-1 respectively. The experiments were carried out in a Randomized Block Design (RBD) with a plot size of 5 x 5 meters (25 m2), and each treatment was replicated 4 times for randomization. The following treatments are as per the recommendations of M/s. Novozymes South Asia Pvt. Ltd. was adopted to study the effect of the products listed in Table 1.

**Table 1. Treatment details**

|  |  |  |
| --- | --- | --- |
|  | **Treatment details** | **Rate and unit** |
| T1 | RhizoMyx Eco Gr-1 (Control) | 4 kg/ac |
| T2 | RhizoMyx Eco Gr- 2 | 4 kg/ac |
| T3 | RhizoMyx Eco Gr- 3 | 4 kg/ac |
| T4 | RhizoMyx Eco Gr- 4 | 4 kg/ac |
| T5 | RhizoMyx Eco Gr- 5 | 4 kg/ac |
| T6 | RhizoMyx Eco Gr- 6 | 3 kg/ac |
| T7 | RhizoMyx Eco Gr- 7 | 4 kg/ac |
| T8 | RhizoMyx Eco Gr- 8 | 4 kg/ac |

**2.2. Crop cultivation practices**

The experimental field was ploughed twice, and the generalized recommendation recommended for the location, consisting of 150:50:50 kg N, P2O5, and K2O ha-1 in terms of urea (N), super phosphate (P), and Murate of potash (K) was applied. Nitrogen and Potassium were applied in three split doses *i.e.,* 50% as basal, 25% each at active tillering stage and panicle initiation stages, and 100% of phosphorus was applied as a basal dose.

Seeds of Paddy variety VDG 1 were kept for pre-germination, and seeds were soaked in water for 24 hours to encourage imbibition. After soaking, the seeds were drained and dark environment for another 12-24 hours for the emergence of radical, which indicates the pre-germination. Finally, the pre-germinated seeds were sown in the nursery with proper spacing and covered with dry soil.

**2.3** **Measurement of plant morphology and yield traits**

Biometric observations were recorded from five randomly selected plants per plot in each replication at three critical growth stages, viz., Maximum tillering, panicle initiation, and harvest. These observations were conducted to evaluate the bioefficacy of various RhizoMyx Eco Gr formulations (developed by Novozymes South Asia Pvt. Ltd.) on paddy (Variety VDG 1). Plant height was measured from the soil surface to the tip of the panicle between 45 to 50 days after transplanting (DAT), and the average height was expressed in centimeters. The average number of tillers per plant and the number of productive tillers per clump were also manually counted during the same period (45–50 DAT). Lodging severity was visually assessed at maturity and recorded as the percentage of plants exhibiting lodging. Furthermore, the number of well-filled grains in the primary panicle of each plant was recorded.

The main panicle was measured from the neck of the panicle to the tip, and the length was recorded at harvest in centimetres (cm). The weight of the thousand filled grains was randomly selected, and the weight of the grain was recorded and expressed in grams (g). The tagged crops from each treatment were harvested and threshed separately. The grains were sundried for three days (14% moisture level) and the straw for 10 days for complete drying. Grain yield and Straw Yield was recorded in grams. Plants with panicles were dried and weighed, and expressed in grams. The harvest index was worked out by using the following formula.

**Harvest index = (Grain yield) / (Straw yield) X100**

**2.4** **Statistical analysis**

The experiment was conducted using a Randomized Complete Block Design (RCBD) with four replications. Data were analyzed by ANOVA to evaluate treatment effects, and significant differences among means were determined using the Least Significant Difference (LSD) test at a 5% significance level (p < 0.05). Statistical analyses were performed using R Studio software.

**3. RESULT AND DISCUSSION**

**3.1 Effect of RhizoMyx Eco Gr products on vigour and plant height of paddy (Var: VDG1)**

The study examined the effect of various treatments of RhizoMyx Eco Gr on the vigour of paddy plants of the VDG1 variety. The vigour scores ranged from 3.50 to 4.00. The highest vigour scores (4.00) were observed in Treatments 2 (RhizoMyx Eco Gr-2) and 6 (RhizoMyx Eco Gr-6), as well as in Treatment 4 (RhizoMyx Eco Gr-4). In contrast, the lowest vigour scores of 3.50 were recorded in Treatments 5 (RhizoMyx Eco Gr-5) and 8 (RhizoMyx Eco Gr-8). This indicates that certain treatments of RhizoMyx Eco Gr significantly enhance the vigour of paddy plants. (Table 2). In terms of plant height, a minimum height of 21.28 cm was recorded for Treatment 1 and a maximum height of 35.95 cm for Treatment 2. The other treatments recorded heights as follows: Treatment 3 (23.75 cm), Treatment 4 (25.43 cm), Treatment 5 (29.95 cm), Treatment 6 (33.85 cm), Treatment 7 (28.60 cm), and Treatment 8 (32.48 cm). These findings highlight the significant impact that specific treatments of RhizoMyx Eco Gr can have on enhancing the height of paddy plants. (Table 2) These findings are consistent with previous research indicating that combining biofertilizers with chemical fertilizers improves rice growth parameters. Noraida and Hisyamuddin (2021) found that a 50:50 biofertilizer-to-NPK ratio significantly improved plant height. Furthermore, studies by Nataraja et al. (2021) and Baghel and Singh (2025) support the conclusion that integrating biofertilizers with recommended or reduced chemical fertilizer doses promotes sustainable nutrient management, resulting in taller plants, better nutrient uptake, and improved yield. Together, these insights reinforce the efficacy of RhizoMyx Eco Gr as a biofertilizer that not only boosts paddy growth but also contributes to more sustainable, efficient fertilizer use.

**Table 2. Effect of RhizoMyx Eco Gr on vigour, plant Height and tiller count of Paddy (Var: VDG1)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **TREATMENT** | **Vigour** | **Plant height (cm)**  **45-60 DAT** | **Total tillers/m2** | **Productive tillers/m2** |
| **RhizoMyx Eco Gr-1 (Control)** | 3.75a | 21.28e | 406.25e | 360.75d |
| **RhizoMyx Eco Gr- 2** | 4.00a | 35.95a | 620.75a | 591.50a |
| **RhizoMyx Eco Gr- 3** | 3.75a | 23.75d | 445.25de | 399.75cd |
| **RhizoMyx Eco Gr- 4** | 4.00a | 25.43d | 451.75ce | 409.50c |
| **RhizoMyx Eco Gr- 5** | 3.50a | 29.95c | 494.00bcd | 458.25b |
| **RhizoMyx Eco Gr- 6** | 4.00a | 33.85b | 604.50a | 568.75a |
| **RhizoMyx Eco Gr- 7** | 3.75a | 28.60c | 497.25bc | 461.50b |
| **RhizoMyx Eco Gr- 8** | 3.50a | 32.48b | 529.75b | 497.25b |
| **SEM** | 0.22 | 2.46 | 11.39 | 11.28 |
| **CD (5%)** | 0.64 | 7.16 | 24.57 | 24.46 |
| **CD (1%)** | 0.88 | 9.74 | 26.98 | 26.41 |

The results were represented as the mean of four independent experiments. Labelled with different letters indicates statistical significance

**3.2 Effect of RhizoMyx Eco Gr products on tiller count of paddy (Var: VDG1)**

The results of the present investigation demonstrate that different formulations of RhizoMyx Eco Gr exert varying degrees of influence on the total and productive tiller count of paddy (Variety: VDG1). Among the treatments, RhizoMyx Eco Gr-2 (T2) consistently outperformed all others, recording the highest total tiller count (620.75 tillers/m²) and the highest productive tiller count (591.50 tillers/m²). This indicates a strong potential of RhizoMyx Eco Gr-2 in promoting vegetative growth and enhancing paddy productivity. This trend is closely followed by RhizoMyx Eco Gr-6 (T6), which achieved 604.50 total tillers/m² and 568.75 productive tillers/m², also marking it as a highly effective treatment. RhizoMyx Eco Gr-8 (T8) was the third most effective, with 529.75 total tillers/m² and 497.25 productive tillers/m². T5 and T7 showed moderate effects, while T4 and T3 were comparatively less effective. Notably, RhizoMyx Eco Gr-1 (Control) (T1) demonstrated the least effectiveness, recording the lowest values in both total (406.25 tillers/m²) and productive tillers (360.75 tillers/m²) (Table 2). These findings are consistent with previous research highlighting the synergistic benefits of biofertilizer applications. The current results reinforce these observations, particularly with RhizoMyx Eco Gr-2, which appears to be the most effective in stimulating tillering. Additionally, Agake et al (2022) highlighted that long-term application of biofertilizers enhances nitrogen uptake and leads to increases in tiller number and key yield components. The high tiller counts observed with RhizoMyx Eco Gr-2 and Gr-6 may thus be attributed to improved nitrogen availability and microbial activity in the rhizosphere, contributing to overall plant vigour.

**3.3 Effect of RhizoMyx Eco Gr products on average grains per panicle and panicle length of paddy (Var: VDG1)**

The evaluation of the impact of various RhizoMyx Eco Gr treatments on the yield quality of paddy (Var: VDG1) demonstrated notable differences in both average grains per panicle and panicle length. The treatment T2 - RhizoMyx Eco Gr-2 exhibited the highest average grains per panicle, with a count of 257.25 grains, followed by T6 - RhizoMyx Eco Gr-6 at 254.50 grains, and T5 - RhizoMyx Eco Gr-5, which produced 246.50 grains. Treatment T8 - RhizoMyx Eco Gr-8 yielded 246.75 grains, while T7 - RhizoMyx Eco Gr-7 had an average of 242.75 grains. The remaining treatments, T4 - RhizoMyx Eco Gr-4 and T3 - RhizoMyx Eco Gr-3, resulted in 233.00 and 227.00 grains, respectively, with T1 - RhizoMyx Eco Gr-1 (Control) showing the lowest yield at 215.25 grains per panicle. (Table 3) Regarding panicle length, treatment T2 - RhizoMyx Eco Gr-2 again led with a length measurement of 24.73 cm, followed by T6 - RhizoMyx Eco Gr-6 at 24.23 cm. Treatment T5 - RhizoMyx Eco Gr-5 achieved a panicle length of 23.13 cm, closely followed by T8 - RhizoMyx Eco Gr-8 at 23.83 cm. Other treatments included T4 - RhizoMyx Eco Gr-4 with a length of 22.03 cm, T7 - RhizoMyx Eco Gr-7 at 22.53 cm, and T3 - RhizoMyx Eco Gr-3 at 20.93 cm. T1 - RhizoMyx Eco Gr-1 (Control) recorded the shortest panicle length at 20.00 cm. These findings underscore the significant influence of RhizoMyx Eco Gr treatments on key yield characteristics of paddy, indicating the potential for optimizing agricultural practices to enhance productivity (Table 3). According to Islam et al. (2012), the application of *Azospirillum* biofertilizer led to a marked improvement in panicle length, alongside other growth parameters such as plant height and tiller number. This improvement is likely due to the enhanced nitrogen fixation and growth-promoting substances (like indole-3-acetic acid) produced by *Azospirillum*, which stimulate root development and nutrient uptake, leading to more vigorous panicle formation. Moreover, Patriyawaty and Agustina (2022) highlighted those optimal combinations of biofertilizer type, dosage, and plant spacing significantly influence panicle length. Their study underscores the importance of tailoring agronomic practices to specific biofertilizer formulations and field conditions to maximize yield benefits. This suggests that panicle length improvement is not solely dependent on the biofertilizer type but also on how it is integrated into the cultivation system. In addition, Naher *et al.* (2016) demonstrated that combining biofertilizers with reduced chemical fertilizers not only maintained but, in some cases, enhanced panicle length and overall yield performance. This supports a more sustainable approach to rice farming, reducing reliance on synthetic inputs while maintaining crop productivity. The results point to the efficiency of biofertilizers in compensating for reduced NPK input, likely through improved soil microbial activity and nutrient cycling.

**3.4 Effect of RhizoMyx Eco Gr products on seed test weight and 1000 grain weight of paddy (Var: VDG1)**

The treatments T2-RhizoMyx Eco Gr-2 and T6-RhizoMyx Eco Gr-6 exhibited the highest seed test weight, both measuring 18.53 grams (Table 3). Treatment T5-RhizoMyx Eco Gr-5 followed closely with a seed test weight of 18.50 grams, and T8-RhizoMyx Eco Gr-8 recorded a weight of 18.48 grams. Subsequently, treatments T4-RhizoMyx Eco Gr-4 and T7-RhizoMyx Eco Gr-7 showed equivalent seed test weights of 18.43 grams. T3-RhizoMyx Eco Gr- 3 had a seed test weight of 18.40 grams, while T1-RhizoMyx Eco Gr-1 (Control) represented the lowest seed test weight at 18.35 grams. (Table 3) The variance in seed test weights among the different treatments signifies the potential impact of RhizoMyx Eco Gr on enhancing paddy yield quality, with statistical measures indicating significance in the observed differences. Seed treatments with biofertilizers, as shown by Saryoko and Kusumawati (2021), resulted in increased panicle numbers and seed yield, contributing to a higher 1000-grain weight. Similarly, Pathirana and Yapa (2020) and Turmuktini et al*.* (2012) reported that the combination of compost and biofertilizers produced the highest seed weights and overall yield improvements. Furthermore, Turmuktini et al. (2012) emphasized that such integration not only boosts fertilizer efficiency but also contributes to soil health restoration, reinforcing the role of biofertilizers in promoting sustainable and productive paddy systems. This suggests that specific formulations of RhizoMyx Eco Gr may optimize seed characteristics, contributing to better agricultural outcomes.

**Table 3. Effect of RhizoMyx Eco Gr on panicle length, grain and yield of Paddy (Var: VDG 1)**

The results were represented as the mean of four independent experiments. Labelled with different letters indicates statistical significance

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **TREATMENT** | **PANICLE** | | **GRAIN** | | **YIELD** | | |
| **Average grains/ panicle** | **Panicle length (cm)** | **Seed test weight (g)** | **1000 grain weight (g)** | **Grain Yield**  **(kg/ha)** | **Straw Yield (kg/ha)** | **Harvest Index** |
| **RhizoMyx Eco Gr-1 (Control)** | 215.25e | 20.00e | 18.35a | 18.35a | 5980.00e | 9390.00e | 0.63 |
| **RhizoMyx Eco Gr- 2** | 257.25a | 24.73a | 18.53a | 18.53a | 7270.00a | 11710.00a | 0.62 |
| **RhizoMyx Eco Gr- 3** | 227.00de | 20.93e | 18.40a | 18.40a | 6250.00de | 10140.00de | 0.64 |
| **RhizoMyx Eco Gr- 4** | 233.00cd | 22.03d | 18.43a | 18.43a | 6420.00cd | 10350.00cd | 0.62 |
| **RhizoMyx Eco Gr- 5** | 246.50ab | 23.13bc | 18.50a | 18.50a | 6880.00ab | 11000.00ad | 0.63 |
| **RhizoMyx Eco Gr- 6** | 254.50ab | 24.23a | 18.53a | 18.53a | 7180.00a | 11540.00ab | 0.62 |
| **RhizoMyx Eco Gr- 7** | 242.75bc | 22.53cd | 18.43a | 18.43a | 6740.00bc | 10740.00bd | 0.63 |
| **RhizoMyx Eco Gr- 8** | 246.75ab | 23.83ab | 18.48a | 18.48a | 6930.00ab | 11110.00abc | 0.62 |
| **SEM** | 6.89 | 0.77 | 0.05 | 0.4 | 10.88 | 17.59 | - |
| **CD (5%)** | 20.07 | 1.10 | 0.14 | 1.16 | 58.67 | 69.25 | - |
| **CD (1%)** | 27.28 | 2.27 | 0.19 | 1.58 | 77.62 | 85.59 | - |

**3.5 Effect of RhizoMyx Eco Gr products on grain and straw yield of paddy (Var: VDG1)**

The maximum grain yield was observed in treatment T2 (RhizoMyx Eco Gr-2), 7270 kg/ha, indicating that this treatment significantly enhances productivity compared to others (Table 3). Similarly, the straw yield followed a parallel trend, with treatment T2 not only leading in grain yield but also producing the maximum straw yield of 11710 kg/ha, contributing positively to biomass, which is essential for soil health. These findings emphasize the effectiveness of RhizoMyx Eco Gr treatments in enhancing paddy productivity, with T2 emerging as the optimal choice for farmers seeking to maximize both grain and straw output. Harvest index for various treatments of RhizoMyx Eco Gr applied to paddy variety ADT-43. The harvest indices for the treatments range from 0.62 to 0.64. Overall, the results indicate similar harvest performance across most treatments, suggesting consistent effectiveness of RhizoMyx Eco Gr on yield. Several studies, including those by Islamet al. (2012), and Turmuktini et al. (2012), report substantial increases in both grain and straw yields up to 19.71% when biofertilizers such as *Azospirillum* and *Trichoderma* are applied, demonstrating their efficacy compared to conventional fertilisation methods. This increase in productivity is coupled with notable cost savings, with Naher et al. (2016) observing up to 45.74% reduction in input costs when biofertilizers are used in conjunction with reduced chemical fertilizers, without compromising yield.

**4. CONCLUSION**

The results of the study concluded that RhizoMyx Eco Gr-2 (T2) is the most effective formulation for promoting growth and enhancing yield in paddy cultivation. This treatment led to a significant increase in plant vigour, with scores rising from 3.75 to 4.00, and plant height increased from 21.28 cm to 35.95 cm. It also resulted in the highest number of tillers, with total and productive tillers reaching 406.25 and 360.75 per m², respectively. Moreover, RhizoMyx Eco Gr-2 yielded the highest grain production, with grain yield rising from 5980 kg/ha in the control to 7270 kg/ha, representing a 21.6% increase, and straw yield increasing from 9390 kg/ha to 11710 kg/ha, a 24.7% improvement. Additionally, the seed test weight was among the highest at 18.53 grams, and the treatment showed the highest panicle length (27.25 cm) and grains per panicle (257.25 grains). These improvements collectively demonstrate that RhizoMyx Eco Gr-2 significantly boosts crop growth and yield parameters, confirming its potential as an effective, sustainable biofertilizer for rice cultivation.

**ACKNOWLEDGEMENT**

The authors express their sincere gratitude to M/s. Novozymes South Asia Pvt. Ltd., Bangalore, for funding and supporting the research project No. BE/NSA/NRM/TRY/SSAC/2020/R001. The authors gratefully acknowledge Tamil Nadu Agricultural University (TNAU) and the Department of Soil Science and Agricultural Chemistry, Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli, for providing the necessary facilities and infrastructure for the successful execution of the field trials. The authors also appreciate the support of the technical staff and field workers at the Sugarcane Research Station, Melalathur, whose assistance in field operations and data collection was instrumental in the completion of this project.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Mode (ChatGPT, COPILOT, QUILLBOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**REFERENCES:**

Agake, S. I., Ohwaki, Y., Kojima, K., Yoshikawa, E., Artigas Ramirez, M. D., Bellingrath-Kimura, S. D., and Yokoyama, T. (2022). Biofertilizer with Bacillus pumilus TUAT1 spores improves growth, productivity, and lodging resistance in forage rice. *Agronomy*, 12(10), 2325.

Ahmadi, N., Audebert, A., Bennett, M. J., Bishopp, A., de Oliveira, A. C., Courtois, B., Diedhiou, A., Diévart, A., Gantet, P., Ghesquière, A., Guiderdoni, E., Henry, A., Inukai, Y., Kochian, L., Laplaze, L., Lucas, M., Luu, D. T., Manneh, B., Mo, X., Xu, J. (2014). The roots of future rice harvests. *Rice*, 7(1), 29.

Baghel, S., and Singh, A. K. (2025). Effect of Different Bio-Fertilizer on Plant and Soil in Different Stages of Rice in Vertisol of Chhattisgarh Plain, India. *International Journal of Plant and Soil Science*, 37(5), 10-9734.

Bhardwaj, D., Ansari, M. W., Sahoo, R. K., & Tuteja, N. (2014). Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. *Microbial Cell Factories*, 13(1), 66.

DAC&FW. (2023). Agricultural Statistics at a Glance 2023, Ministry of Agriculture & Farmers Welfare.

ICAR. (2023). Annual Report of Indian Council of Agricultural Research.

Islam, M. Z., Sattar, M. A., Ashrafuzzaman, M., Saud, H. M., and Uddin, M. K. (2012). Improvement of yield potential of rice through combined application of biofertilizer and chemical nitrogen. *African Journal of Microbiology Research*, 6(4), 745-750.

John, S. A., and Ray, J. G. (2023). Optimization of environmental and the other variables in the application of arbuscular mycorrhizal fungi as an ecotechnological tool for sustainable paddy cultivation: a critical review. *Journal of Applied Microbiology*, 134(6). <https://doi.org/10.1093/jambio/lxad111>

Mallareddy, M., Thirumalaikumar, R., Balasubramanian, P., Naseeruddin, R., Nithya, N., Mariadoss, A., Eazhilkrishna, N., Choudhary, A. K., Deiveegan, M., Subramanian, E., Padmaja, B., and Vijayakumar, S. (2023). Maximizing Water Use Efficiency in Rice Farming: A Comprehensive Review of Innovative Irrigation Management Technologies. *Water*, 15(10), 1802. https://doi.org/10.3390/w15101802.

Mohidem, N. A., Hashim, N., Shamsudin, R., and Che Man, H. (2022). Rice for Food Security: Revisiting Its Production, Diversity, Rice Milling Process and Nutrient Content. *Agriculture*, 12(6), 741. https://doi.org/10.3390/agriculture12060741

Naher, U. A., Panhwar, Q. A., Othman, R., Ismail, M. R., and Berahim, Z. (2016). Biofertilizer as a supplement of chemical fertilizer for yield maximization of rice. *Journal of Agriculture Food and Development*, 2(0), 16-22.

Nataraja, T. H., Naika, R., Shankarappa, S. K., Reddy, K. V., Abdelmohsen, S. A., Al-Harbi, F. F., and Abdelbacki, A. M. (2021). Productivity of paddies as influenced by varied rates of recommended nutrients in conjunction with biofertilizers in local landraces. *Agronomy*, 11(6), 1165.

Noraida, M. R., & Hisyamuddin, M. R. A. (2021). The effect of different rate of biofertilizer on the growth performance and yield of rice. *IOP Conference Series Earth and Environmental Science*, *757*(1), 012050. https://doi.org/10.1088/1755-1315/757/1/012050

Pathirana, B. K. W., and Yapa, P. N. (2020). Evaluation of different carrier substances for the development of an effective pelleted biofertilizer for rice (Oryza sativa L.) using co-inoculated bacteria and arbuscular mycorrhizal fungi. *Asian Journal of Biotechnology and Bioresource Technology*, 6(1), 1-10. http://dx.doi.org/10.9734/ajb2t/2020/v6i130070.

Patriyawaty, N. R., Yursida, N., Agustina, K., & Ikhwani, N. (2022). Growth and yield response of lowland rice to form and dosage of bio-fertilizer at different plant spacing. *IOP Conference Series Earth and Environmental Science*, 995(1), 012008. https://doi.org/10.1088/1755-1315/995/1/012008.

Piliarová, M., Ondreičková, K., Hudcovicová, M., Mihálik, D., and Kraic, J. (2019). Arbuscular Mycorrhizal Fungi – Their Life and Function in Ecosystem. *Agriculture* (*PolNohospodárstvo*), 65(1), 3–15.

https://doi.org/10.2478/agri-2019-0001

Saryoko, A., Kusumawati, S., & Pohan, A. (2021c). Seed treatment using biofertilizer to improve plant growth and yield performances of upland rice cultivars under various planting densities. *IOP Conference Series Earth and Environmental Science*, *648*(1), 012028. https://doi.org/10.1088/1755-1315/648/1/012028.

Turmuktini, T., Kantikowati, E., Natalie, B., Setiawati, M., Yuwariah, Y., Joy, B., and Simarmata, T. (2012). Restoring the health of paddy soil by using straw compost and biofertilizers to increase fertilizer efficiency and rice production with SOBARI (System of Organic Based Aerobic Rice Intensification) technology. *Asian Journal of Agriculture and Rural Development*, 2(4), 519-526.

USDA. (2024). India Grain and Feed Annual Report.

Vessey, J. K. (2003). Plant growth promoting rhizobacteria as biofertilizers. *Plant and Soil*, 255(2), 571–586.

Yashavantha Rao, H. C., Chandra Mohana, N., and Satish, S. (2020). Biocommercial aspects of microbial endophytes for sustainable agriculture. In Microbial Endophytes (pp. 323–347). *Elsevier*.