Effect of Nitrogen and Phosphorus on Yield and Yield attributes of Rice (*Oryza sativa* L.)

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| **Abstract**  This study investigated the effects of nitrogen (N) and phosphorus (P) fertilization on the growth, yield, and yield-related attributes of rice (*Oryza sativa* L.) under submerged conditions at Yezin Agricultural University, Myanmar. The experiment utilized a factorial randomized complete block design, testing four N levels (0, 43, 86, and 129 kg N ha⁻¹) and four P levels (0, 6, 12, and 18 kg P ha⁻¹), with three replications during both dry and wet seasons using the Sin Thu Kha rice variety. Results showed that increasing N levels significantly improved plant height, tiller number, SPAD readings, and yield components in both seasons, with maximum yields achieved at 129 kg N ha⁻¹. Phosphorus application also positively influenced growth and yield parameters, though its impact was less pronounced than N, with optimal results observed at 12–18 kg P ha⁻¹. Significant interaction effects between N and P were noted across most parameters, highlighting synergistic nutrient interactions. Notably, N and P had a stronger influence on grain yield during the wet season compared to the dry season. The highest grain yield was obtained with 129 kg N ha⁻¹ and 18 kg P ha⁻¹, highlighting the importance of balanced fertilization for maximizing productivity. These findings offer practical guidelines for optimizing fertilizer use in Myanmar's rice production and emphasize the need for integrated nutrient management tailored to seasonal variations. |

***Keywords****: Nitrogen, Phosphorus, Rice Yield,* *grain, fertilization*

1. INTRODUCTION

Rice (*Oryza sativa* L.), a cornerstone of global agriculture, serves as the primary staple food for more than half of the world’s population and plays a pivotal role in ensuring global food security (Prom-U-Thai and Rerkasem, 2020). In Myanmar, rice is not only a dietary staple but also a critical driver of economic growth, employment generation, and export revenue. It occupies approximately 60% of the total cultivated land area, making it the backbone of the country's agricultural sector (Connor et al., 2022). Rice production significantly contributes to Myanmar's gross domestic product (GDP) and supports the livelihoods of millions of rural households (Kurosaki, 2008). Despite its agronomic and socioeconomic importance, rice cultivation in Myanmar faces multifaceted challenges, including nutrient-deficient soils, water scarcity, pest infestations, and climate variability, which collectively hinder productivity and sustainability.

Among these challenges, nutrient management particularly the application of nitrogen (N) and phosphorus (P) is a key determinant of rice yield and quality under submerged conditions. The present day of farming in N management leads to over-application can cause excessive vegetative growth, lodging, and increased vulnerability to pests and diseases in addition to causing environmental hazards. Whereas optimum phosphorus management ensures healthy plant establishment and high grain quality, but undergoes various forms of unavailable forms of P. In this context, the present study highlights the optimum supplementation of N and P for enhancing productivity of Rice (Budiono, Adinurani & Soni, 2019). Nitrogen is vital for vegetative growth, influencing leaf development, photosynthesis, and overall plant vigor. It plays a key role in the synthesis of proteins, enzymes, and chlorophyll, which are critical for energy production and growth (Liang, Bao, Li, & Cai, 2015). Adequate nitrogen enhances tillering, root development, and grain filling, leading to higher yields (Zhang et al., 2020). While, Phosphorus is essential for early plant growth, root development, energy transfer, and flowering. It supports the formation of strong root systems, improves nutrient uptake, and enhances seed germination and vigor. Phosphorus is also crucial for the synthesis of nucleic acids and ATP, which are necessary for metabolic activities (Meng et al., 2021). However, the efficiency of N and P fertilizers is often constrained by factors such as soil type, fertilizer application rates, timing, and environmental conditions. Suboptimal fertilizer use can lead to reduced crop yields, while Superoptimal dose poses significant environmental risks, including soil degradation, eutrophication of water bodies, and greenhouse gas emissions (Pahalvi et al., 2021).

The need for optimal nutrient supply with optimum N to P ratio to the face of growing global food demand and environmental concerns. Nutrient management strategies which combines scientific research with traditional knowledge and local practices, offers a promising approach to optimizing fertilizer use while minimizing adverse environmental impacts (Pandey and Diwan, 2018). Understanding the specific effects of nitrogen and phosphorus application on yield and yield-contributing characters of rice under submerged conditions is essential for developing evidence-based recommendations tailored to local agroecological contexts.

The present study aims to investigate the impact of varying nitrogen and phosphorus fertilizer levels on the yield and yield-contributing traits of rice under submerged conditions. The study's objectives align with several Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 12 (Responsible Consumption and Production). By investigating optimal nitrogen and phosphorus fertilizer application rates to maximize rice yields sustainably, the research contributes to improving food security and agricultural productivity while promoting more efficient and environmentally-friendly fertilizer use, thus supporting sustainable agricultural practices and resource management. By elucidating the relationships between nutrient inputs and agronomic performance, the study to aims to evaluate the efffect of nitrogen and phosphorus fertilization on growth and yield of rice and aslo to revalidate the recommended dose of nitrogen and phosphorus rate of application.

**2. MATERIALS AND METHODS**

Two seasons of pot experiments were conducted in the screen house of the Department of Soil and Water Science at Yezin Agricultural University (19°50'08"N, 96°16'42"E) from March to December 2024. The experiment included two factors: Factor A represented four nitrogen levels (0, 43, 86, and 129 kg N ha⁻¹), while Factor B comprised four phosphorus levels (0, 6, 12, and 18 kg P ha⁻¹). Each treatment combination was replicated three times. The rice cultivar used in this study was *Sin Thu Kha*, cultivated during both the dry and wet seasons. The recommended fertilizers dose of *Sin Thu Kha* rice variety is 86 kg N ha-1, 12 kg P ha-1 and 31 kg K ha-1.

Nitrogen was applied in the form of urea, and triple superphosphate was used for phosphorus. The triple superphosphate was applied as a basal dose, whereas urea and potassium were applied in three equal splits: one-third was top-dressed at 10 DAT, and the remainder was top-dressed in two equal splits at 35 DAT and 60 DAT. The experiment was arranged in a Randomized Complete Block Design (RCBD) with three replications.

Twenty-day-old seedlings were transplanted into each 30 cm diameter plastic pot. The following parameters were measured: plant height (cm), number of tillers per hill, panicle length (cm), number of spikelets per panicle, filled grain percentage, 1000 grain weight (g), number of panicles per hill, and grain yield (g plant⁻¹). The data were analyzed using Statistix software (Version 8). All data underwent analysis of variance, and mean separation among treatments was conducted using the Least Significant Difference (LSD) test at a 5% probability level.as described by Gomez (1984).

**Table 1. Pysicochemical properties of experimental soil**

|  |  |
| --- | --- |
| **Parameters** | **Rating** |
| Sand (%) | 82.27 |
| Silt (%) | 11.10 |
| Clay (%) | 6.63 |
| Texture class | Loamy sand |
| pH (1:2.5) | 6.2 (Slightly acid) |
| CEC (Cmol(p+) kg-1) | 2.73 (Very low) |
| EC (dSm-1) | 0.01 (Non-saline) |
| OM (%) | 0.92 (low) |
| Available N (mg kg-1) | 24.23 (Very low) |
| Available P (mg kg-1) | 3 (low) |
| Available K (mg kg-1) | 23 (low) |

**Figure 1. Rainfall, minimum and maximum temperature during experimental period in Yezin**

**3. Results and Discussion**

**3.1 Growth Attributes**

**3.1.1 Dry Season**

**Plant Height:** The application of nitrogen significantly increased plant height at all growth stages (Table 2). At 84 days after transplanting (DAT), the tallest plants were observed with an application of 129 kg N ha⁻¹, measuring 111.62 cm, compared to the shortest plants in the control group (0 kg N ha⁻¹) at 104.04 cm. Phosphorus also positively influenced plant height, though its effect was less pronounced than that of nitrogen (Table 2). Plants treated with 18 kg P ha⁻¹ had a mean height of 107.15 cm at 84 DAT, while those with no phosphorus (0 kg P ha⁻¹) reached a height of 103.76 cm. A significant interaction between nitrogen and phosphorus (N × P) was observed, indicating that their combined application synergistically enhances plant height.

The significant increase in plant height with higher N application rates underlines the critical role of N in promoting vegetative growth. Nitrogen enhances cell elongation and division, which directly contributes to increased plant height (Wang et al., 2022). The marginal but significant contribution of P to plant height emphasizes the complementary roles of these nutrients. P improves root development and energy transfer processes, enabling better nutrient uptake and overall plant growth (Fageria, Knupp, & Moraes, 2013). The significant interaction effects between N and P suggest that their combined application creates synergistic effects, as both nutrients work together to optimize structural growth and metabolic efficiency.

**Number of Tillers Hill⁻¹:** Increasing nitrogen levels significantly enhanced the number of tillers (Table 3). The highest number of tillers (26.92) at 84 DAT was recorded with 129 kg N ha⁻¹, whereas the lowest (23.92) was found in the control group (0 kg N ha⁻¹). Phosphorus contributed to tiller production, with the highest number of tillers (26.92) observed with 18 kg P ha⁻¹ (Table 3). The control group (0 kg P ha⁻¹) exhibited the fewest tillers (25.33). Significant interaction effects (N × P) were noted, emphasizing the importance of balanced N and P fertilization for maximizing tiller production.

Tillering is a key determinant of rice yield, directly influencing the number of productive panicles per unit area. The significant enhancement in tiller production with increased N levels highlights N's role in promoting tillering capacity, especially during later growth stages (Khan et al., 2004). The positive impact of P on tiller production can be attributed to its role in improving root vigor and nutrient uptake efficiency. The significant interaction effects (N × P) further highlight the importance of balanced N and P fertilization for maximizing tiller density, which is crucial for achieving high yields. These findings underscore the need for integrated nutrient management strategies that consider both nutrients simultaneously.

**SPAD Readings:**

Nitrogen significantly increased SPAD readings at all stages (Table 4). The highest readings (40.48) at 84 DAT were observed with 129 kg N ha⁻¹, while the lowest (38.48) were seen in the control group (0 kg N ha⁻¹). Phosphorus did not significantly affect SPAD readings (p > 0.05). No significant interaction effects (N × P) were observed for SPAD readings.

SPAD readings, an indicator of chlorophyll content and photosynthetic capacity, were significantly influenced by increased levels of N but not positively with levels of P application. The observed increase in SPAD values with higher N levels reflects nitrogen's role in chlorophyll synthesis and photosynthesis (Jauhari et al., 2025). These findings are consistent with earlier research indicating that N deficiency limits chlorophyll production, thereby reducing photosynthetic efficiency and grain yield potential (Wang et al., 2022). The lack of significant P effects on SPAD readings suggests that P primarily influences other physiological processes, such as energy metabolism and root development, rather than directly affecting chlorophyll content.

**3.1.2 Wet Season**

**Plant Height:** Similar trends were observed during the wet season, with nitrogen application significantly increasing plant height (Table 2). The tallest plants (106.75 cm at 84 DAT) were observed with 129 kg N ha⁻¹, while the shortest (101.79 cm at 84 DAT) were in the control group (0 kg N ha⁻¹). Phosphorus application improved plant height, with the highest values (105.81 cm at 84 DAT) recorded for 18 kg P ha⁻¹ (Table 2). The lowest values (103.02 cm at 84 DAT) were observed in the control group (0 kg P ha⁻¹). Both nitrogen and phosphorus showed significant interaction effects (N × P), suggesting that combined application enhances plant height more effectively than either nutrient alone.

The significant increase in plant height with higher N application rates aligns with previous findings, highlighting the role of N in enhancing vegetative growth. The marginal but significant contribution of P to plant height emphasizes the complementary roles of these nutrients. The interaction effects demonstrate that integrated N and P management can optimize plant height, providing a structural advantage for higher yields. These findings reinforce the importance of balanced nutrient application for sustainable rice production (Hou et al., 2019).

**Number of Tillers Hill⁻¹:** Similar trends were observed during the wet season, with nitrogen application significantly increasing the number of tillers (Table 3). The highest number of tillers (26.92 at 84 DAT) was observed with 129 kg N ha⁻¹, while the lowest (23.92 at 84 DAT) was in the control group (0 kg N ha⁻¹). Phosphorus application increased tiller production, with the highest values (25.92 at 84 DAT) recorded for 18 kg P ha⁻¹ (Table 3). The lowest values (24.00 at 84 DAT) were observed in the control group (0 kg P ha⁻¹). Significant interaction effects (N × P) were observed, highlighting the importance of balanced N and P fertilization for maximizing tiller production.

The trends in tiller production during the wet season reinforce the critical role of N in promoting tiller formation. The significant interaction effects underscore the need for balanced nutrient management to maximize tiller density and enhance yield potential. The complementary effects of P on tiller production, although less pronounced, indicate its role in supporting root health and nutrient uptake (Fageria et al., 2013).

**SPAD Readings:** Similar trends were observed during the wet season, with nitrogen application significantly increasing SPAD readings (Table 4). The highest values (30.77 at 84 DAT) were observed with 129 kg N ha⁻¹, while the lowest (29.50 at 84 DAT) were in the control group (0 kg N ha⁻¹). Phosphorus had no significant effect on SPAD readings, consistent with the dry season results. No significant interaction effects (N × P) were observed.

The consistent influence of N on SPAD readings across seasons reaffirms its pivotal role in chlorophyll synthesis and photosynthetic efficiency. The absence of significant P effects on SPAD readings suggests that while P is essential for energy transfer and root development, it does not directly influence chlorophyll content or photosynthetic capacity (Jauhari et al., 2025).

**Table 2. Effects of nitrogen and phosphorus fertilizers on plant height of rice at 84 DAT during dry and wet seasons**

|  |  |  |
| --- | --- | --- |
| **Treatments** | **Plant height at 84 DAT**  **(Dry season)** | **Plant height at 84 DAT**  **(Wet season)** |
| N0P0 | 103.87 p | 101.12 o |
| N0P1 | 103.88 o | 101.77 n |
| N0P2 | 104.09 n | 101.93 m |
| N0P3 | 104.32 m | 102.33 l |
| N1P0 | 105.65 l | 102.69 k |
| N1P1 | 105.88 k | 102.89 j |
| N1P2 | 107.86 i | 104.08 h |
| N1P3 | 110.35 f | 105.66 f |
| N2P0 | 107.55 j | 103.63 i |
| N2P1 | 108.09 h | 104.08 h |
| N2P2 | 110.20 e | 105.86 e |
| N2P3 | 111.77 c | 106.92 c |
| N3P0 | 110.06 g | 104.64 g |
| N3P1 | 111.56 d | 106.55 d |
| N3P2 | 112.01 b | 107.48 b |
| N3P3 | 112.84 a | 108.31 a |
| **Pr>F** | **\*\*** | **\*\*** |
| **LSD0.05** | **4.82** | **0.02** |
| **CV%** | **0.01** | **0.02** |

\*Means followed by different letter in the same column are significantly different by LSD test at 5% level.

**Table 3. Effects of nitrogen and phosphorus fertilizers on tillers number of rice at 84 DAT during dry and wet seasons**

|  |  |  |
| --- | --- | --- |
| **Treatments** | **Tillers number at 84 DAT**  **(Dry season)** | **Tillers number at 84 DAT**  **(Wet season)** |
| N0P0 | 23.33 d | 21.00 e |
| N0P1 | 23.45 d | 24.67 d |
| N0P2 | 23.56 d | 25.00 b |
| N0P3 | 23.57 d | 25.00 b |
| N1P0 | 24.32 d | 25.00 b |
| N1P1 | 24.45 d | 25.00 b |
| N1P2 | 26.00 c | 25.00 b |
| N1P3 | 26.00 c | 25.00 b |
| N2P0 | 26.00 c | 25.00 b |
| N2P1 | 26.00 c | 25.00 b |
| N2P2 | 26.00 c | 25.00 b |
| N2P3 | 26.00 c | 25.00 b |
| N3P0 | 26.00 c | 25.00 b |
| N3P1 | 27.00 b | 26.00 c |
| N3P2 | 29.00 a | 28.00 b |
| N3P3 | 29.67 a | 28.67 a |
| **Pr>F** | \*\* | \*\* |
| **LSD0.05** | 0.34 | 0.27 |
| **CV%** | 1.58 | 1.29 |

\*Means followed by different letter in the same column are significantly different by LSD test at 5% level**.**

**Table 4. Effects of nitrogen and phosphorus fertilizers on SPAD values at 84 DAT during dry and wet seasons**

|  |  |  |
| --- | --- | --- |
| **Treatments** | **SPAD values at 84 DAT**  **(Dry season)** | **SPAD values at 84 DAT**  **(Wet season)** |
| N0P0 | 38.10 d | 29.49 b |
| N0P1 | 38.30 cd | 29.50 b |
| N0P2 | 38.50 bcd | 29.52 b |
| N0P3 | 38.80 bcd | 29.54 b |
| N1P0 | 38.87 bcd | 29.56 b |
| N1P1 | 39.57 abcd | 30.05 b |
| N1P2 | 39.77 abcd | 30.06 b |
| N1P3 | 39.79 abc | 30.08 b |
| N2P0 | 39.86 ab | 30.21 b |
| N2P1 | 39.87 ab | 30.23 b |
| N2P2 | 39.89 ab | 30.27 ab |
| N2P3 | 39.90 ab | 30.31 ab |
| N3P0 | 40.43 a | 30.47 ab |
| N3P1 | 40.47 a | 30.53 ab |
| N3P2 | 40.49 a | 30.54 ab |
| N3P3 | 40.52 a | 31.54 a |
| **Pr>F** | ns | ns |
| **LSD0.05** | 0.72 | 0.65 |
| **CV%** | 2.23 | 2.65 |

\*Means followed by different letter in the same column are significantly different by LSD test at 5% level.

**3.2 Yield and Yield-Contributing Traits**

**3.2.1 Dry Season**

**Effect of Nitrogen:** Nitrogen significantly increased grain yield and yield components such as the number of panicles hill⁻¹, spikelets panicle⁻¹, and filled grain percentage (Table 5). The highest grain yield (44.18 g plant⁻¹) was observed with 129 kg N ha⁻¹, while the lowest (37.08 g plant⁻¹) was in the control group (0 kg N ha⁻¹).

The significant increase in grain yield with higher N levels underscores N's critical role in enhancing photosynthesis, promoting vegetative growth, and increasing the number of productive tillers. The improvement in yield components, including the number of spikelets per panicle and filled grain percentage, reflects N's direct influence on cell division, chlorophyll synthesis, and overall plant metabolism (Basosi et al., 2014).

**Effect of Phosphorus:** Phosphorus also improved yield components, with the highest grain yield (42.7 g plant⁻¹) observed with 18 kg P ha⁻¹ (Table 5). The lowest values (38.86 g plant⁻¹) were in the control group (0 kg P ha⁻¹).

While less influential than N, P positively impacted yield components by improving root development and energy transfer processes. The enhancement in panicle length and grain weight with adequate P application highlights its importance in ensuring efficient nutrient uptake and utilization (Abdi et al., 2020).

**Interaction Effects:** Significant interaction effects (N × P) were observed, indicating that balanced N and P fertilization maximizes yield.

The significant interaction effects emphasize the need for integrated nutrient management strategies that consider both nutrients simultaneously. Balanced N and P fertilization not only maximizes yield but also ensures sustainable rice production by minimizing adverse environmental impacts (Hou et al., 2019).

**3.2.2 Wet Season**

**Effect of Nitrogen:** Similar trends were observed during the wet season, with nitrogen application significantly increasing grain yield and yield components (Table 6). The highest grain yield (37.65 g plant⁻¹) was observed with 129 kg N ha⁻¹, while the lowest (27.43 g plant⁻¹) was in the control group (0 kg N ha⁻¹).

The significant impact of nitrogen on yield and its components during the wet season underscores its critical role in promoting vegetative growth, enhancing photosynthesis, and increasing the number of productive tillers. The differences observed are due to nitrogen's role in stimulating tiller initiation and survival, enhancing carbohydrate allocation to lateral buds, and supporting robust vegetative growth (Zhang et al., 2020).

**Effect of Phosphorus:** P application also improved yield components, with the highest grain yield (35.22 g plant⁻¹) observed with 18 kg P ha⁻¹ (Table 6). The lowest values (28.51 g plant⁻¹) were in the control group (0 kg P ha⁻¹).

Interestingly, P exhibited a more pronounced impact on grain yield during the wet season compared to the dry season. This could be attributed to differences in soil moisture and temperature regimes, which may influence nutrient availability and uptake efficiency. The significant effect of phosphorus on yield during the wet season is likely due to improved root development and enhanced energy metabolism, which are crucial for nutrient and water uptake under submerged conditions (Okada et al., 2004).

**Interaction Effects:** Significant interaction effects (N × P) were observed, emphasizing the importance of integrated nutrient management.

These findings suggest that optimizing both nitrogen and phosphorus application rates is crucial for maximizing rice productivity under submerged conditions, particularly during the wet season. The interaction between N and P is significant because their combined application ensures a balanced supply of nutrients, which optimizes plant growth and development, leading to enhanced yield and sustainability (Duncan et al., 2018).

**Table 5. Effects of nitrogen and phosphorus fertilizers on yield and yield components of rice during dry season**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Panicle length (cm)** | **No. of panicles hill-1** | **No. of spikelets panicle-1** | **Filled grain %** | **1000 grain weight (g)** | **Grain yield (g plant-1)** |
|  |
| **Nitrogen** |  |  |  |  |  |  |  |
| 0 kg N ha-1 | 20.81d | 21.67 b | 103.50 c | 69.04 | 19.04 | 37.08 c |  |
| 43 kg N ha-1 | 22.08c | 21.75 c | 109.00 b | 69.91 | 19.13 | 39.17 b |  |
| 86 kg N ha-1 | 22.93c | 22.83 ab | 110.70 b | 69.94 | 19.19 | 41.06 b |  |
| 129 kg N ha-1 | 23.90a | 24.42 a | 120.10 a | 70.08 | 19.31 | 44.18 a |  |
| LSD 0.05 | 0.5 | 1.74 | 5.31 | 1.13 | 0.60 | 1.7 |  |
| **Phosphrous** |  |  |  |  |  |  |  |
| 0 kg P ha-1 | 21.55c | 21.67 b | 106.62 b | 67.78 b | 18.97 | 38.86 b |  |
| 6 kg P ha-1 | 22.12b | 22.25 ab | 106.73 b | 69.91 a | 19.11 | 39.16 b |  |
| 12 kg P ha-1 | 22.84a | 23.08 ab | 110.11 b | 70.12 a | 19.28 | 42.39 a |  |
| 18 kg P ha-1 | 23.21a | 23.67 a | 120.27 a | 70.26 a | 19.30 | 42.70 a |  |
| LSD 0.05 | 0.5 | 1.74 | 5.31 | 1.13 | 0.60 | 1.90 |  |
| **Pr ≥ F** |  |  |  |  |  |  |  |
| Nitrogen | \*\* | \*\* | \*\* | ns | ns | \*\* |  |
| Phosphrous | \* | ns | \*\* | \* | ns | \*\* |  |
| N x P | \* | ns | \*\* | ns | ns | \*\* |  |
| CV % | 2.69 | 9.20 | 5.74 | 1.94 | 3.70 | 5.14 |  |

\*Means followed by different letter in the same column are significantly different by LSD test at 5% level.

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**Table 6. Effects of nitrogen and phosphorus fertilizers on yield and yield components of rice during wet season**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Panicle length (cm)** | **No. of panicles hill-1** | **No. of spikelets panicle-1** | **Filled grain %** | **1000 grain weight (g)** | **Grain yield (g plant-1)** |
|  |
| **Nitrogen** |  |  |  |  |  |  |  |
| 0 kg N ha-1 | 20.87 b | 12.50 b | 80.01 b | 84.39 | 18.52 | 27.43 c |  |
| 43 kg N ha-1 | 21.13 b | 13.83 b | 83.77 b | 84.43 | 18.56 | 28.93 bc |  |
| 86 kg N ha-1 | 21.84 a | 16.75 a | 97.79 a | 84.48 | 18.75 | 30.33 b |  |
| 129 kg N ha-1 | 22.29 a | 17.33 a | 105.70 a | 87.51 | 18.78 | 37.65 a |  |
| LSD 0.05 | 0.45 | 2.01 | 9.95 | 3.05 | 0.37 | 2.62 |  |
| **Phosphrous** |  |  |  |  |  |  |  |
| 0 kg P ha-1 | 21.16 b | 13.75 c | 83.87 b | 84.39 | 18.55 | 28.51 c |  |
| 6 kg P ha-1 | 21.20 b | 14.08 bc | 84.12 b | 84.43 | 18.56 | 28.60 c |  |
| 12 kg P ha-1 | 21.26 b | 15.83 ab | 87.46 b | 84.48 | 18.58 | 31.99 b |  |
| 18 kg P ha-1 | 22.51 a | 16.75 a | 111.82 a | 95.80 | 18.92 | 35.22 a |  |
| LSD 0.05 | 0.45 | 2.01 | 9.95 | 3.05 | 0.37 | 2.62 |  |
| **Pr ≥ F** |  |  |  |  |  |  |  |
| Nitrogen | \*\* | \*\* | \*\* | ns | ns | \*\* |  |
| Phosphrous | \*\* | \*\* | \*\* | ns | ns | \*\* |  |
| N x P | \* | ns | \*\* | ns | ns | \*\* |  |
| CV % | 3.41 | 15.98 | 13.01 | 4.29 | 2.32 | 10.11 |  |

\*Means followed by different letter in the same column are significantly different by LSD test at 5% level.

**Figure 2. Mean values of grain yield (g plant-1) as affected by different rates of nitrogen and phosphorus fertilizers during the dry and wet seasons**

**4. Conclusion**

This study investigated the effects of N and P fertilizers on the growth and yield-contributing characters of rice under submerged conditions at Yezin Agricultural University during dry and wet seasons. The findings revealed that nitrogen significantly influenced plant height, number of tillers hill⁻¹, SPAD readings, and yield components during both dry and wet seasons, with optimal results observed at 129 kg N ha⁻¹. P also positively influenced these parameters, though its effects were less pronounced compared to N, with the highest values recorded at 18 kg P ha⁻¹. The interaction between N and P was significant across most parameters, indicating their synergistic effects when applied together.

Considering the economic implications, a cost-benefit analysis (B:C ratio) was performed to finalize the optimal levels of P. The analysis indicated that both 12 kg P ha⁻¹ and 18 kg P ha⁻¹ are on par with each other in terms of yield benefits relative to fertilizer costs. Therefore, we recommend either level based on specific farmer preferences and local availability. The identified optimal application rates (129 kg N ha⁻¹ and 12-18 kg P ha⁻¹) provide actionable guidelines for farmers in Myanmar to enhance yields sustainably. However, the study's limitations, such as its controlled pot conditions and the absence of a long-term environmental impact assessment, highlight the necessity for field validation and more extensive research on soil health.

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

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