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# Evaluating the effects of nitrogen application on the agricultural performance of improved rice varieties in Marin, Sindhuli, Nepal

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## Abstract

This study focuses the agronomic performance of two rice varieties, Ram Dhan and Sabitri Dhan, under varying nitrogen levels in central inner terai Sindhuli, Nepal, conducted from June to October 2022. The primary motivation is to understand the nuanced impacts of nitrogen application on key physiological traits and yield components without assuming statistically significant differences. The central problem addressed is to explore how different nitrogen levels interact with these traits and influence overall crop productivity. Our study hypothesizes that nitrogen application may affect agronomic parameters such as flag leaf characteristics, culm dimensions, tiller number, flowering dynamics, panicle morphology, and grain yield. The experiment utilized a factorial randomized block design with six treatments and four replications, applying nitrogen levels (100 kg/ha, 120 kg/ha, 140 kg/ha) at split doses during critical growth stages. Data collection included meticulous measurement of these traits following standard agronomic protocols. Key findings revealed that while Sabitri Dhan tended to show higher tiller numbers and panicle traits compared to Ram Dhan, Ram Dhan exhibited marginally better grain yield and harvest index. These results suggest that despite the absence of statistically significant differences, there are practical implications for rice cultivation practices in similar agro-ecological contexts. The study underscores the importance of considering non-significant results in agricultural research to refine nutrient management strategies and enhance crop productivity sustainably. Future research could further explore the nuanced interactions between nitrogen levels and rice varieties to optimize agronomic practices tailored to local conditions and improve yield stability and resilience in rice cultivation.

**Keywords:** Varieties; Nitrogen Levels; Growth; Yield

## 1. Introduction

Rice (*Oryza sativa* L.) is one of the most important grain crops for more than 50% of the world's population, providing approximately 20% of the total energy intake for humans [1]. Rice is also a substantial part of the protein intake for about 520 million people living in poverty in Asia. More than 2000 million people in Asia obtain 70% of their calories from rice and its products [2]. China is the highest producer of 1148.277 million tons globally, followed by India's 120.544 million metric tons. [1].

Nepal's food security relies heavily on the production of staple cereals, with rice as the primary crop. In 2020, rice was cultivated on 1.47 million hectares in Nepal, yielding an average of 3.82 tons per hectare, resulting in a total annual production of 5.6 million tons. [3]. It contributes 20% to the agricultural gross domestic product (AGDP) and more than 7% to the gross domestic product (GDP), [4]. Nepal is one of the important centers of rice genetic resources [5], having

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over 1,700 land races of rice. Rice is cultivated under diversified agro-climatic zones in Nepal from terai (50masl) to mid-hills and high mountains valley (3050masl) in Jumla (the highest altitude of rice growing location in the world) [6].

Nutrient management is an important part of the soil and plant management system. Sixteen nutrients are considered important for rice, where N, P, and K are the primary macronutrients; Mg, Ca, and S are secondary macronutrients; and Zn, Fe, Mn, Cu, B, Mo, and Cl are micronutrients. Nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) are the most important nutrients for plants [7]. The subsequent factors influence Nitrogen in rice yield and consistency organ construction, physiological attributes, component synthesis, and their dissemination [8].

The amount of nitrogen affects the percentage of light penetration, photosynthesis active radiation, light use efficiency, and dry matter partitioning to different parts. Dry matter partitioning to the reproductive organs depends on the number, capacity, and activity of physiological sinks [9]. Nitrogen is an essential plant nutrient being a component of amino acids, nucleic acids, nucleotides, chlorophyll, enzymes, and hormones. Nitrogen is most commonly needed throughout the early to mid-tillage phase for the Initiation of panicles, grain development, and booting stages [7]. The application of the nitrogen fertilizer maximizes rice yield ability by steadily increasing plant height, spikelet count, panicle numbers as well as the number of filled spikelet [10].

The yield potential of improved rice is higher than modern high-yielding improved varieties of rice. The fertilizer recommendation is higher in improved rice than in high-yielding conventional-bred rice [11]. Improved rice could be one option to increase rice yield without increasing rice areas in Nepal [12]. Both Ram and Sabitri are improved varieties of Nepal. Ram Dhan is less cultivated than Sabitri. Sabitri is a popular high-yielding but drought-susceptible variety of Nepal. Being preferred by farmers and consumers, it covers a large area under rainfed and irrigated lowland conditions in Nepal [13].

The main purpose of this research is to determine the optimal nitrogen levels that enhance the growth, yield, and overall productivity of improved rice varieties in Marin, Sindhuli, Nepal. By analyzing the results, the study aims to identify specific nitrogen application rates that maximize crop performance while ensuring sustainable agricultural practices. The discussion of the findings highlights the impact of nitrogen on various growth parameter and yield components, providing valuable insights for farmers and agricultural practitioners in optimizing nitrogen management for improved rice production in the region.

## 2. Materials And Methods

### 2.1. Site Description

The experiment was conducted in central inner terai Sindhuli, Nepal from June to October. It is located 299 meters above mean sea level and lies at 85.7334735 East longitude, and 27.2645948 North latitude.

### 2.2. Soil Physicochemical Properties and Climate of The Experimental Site

The physicochemical properties of the soil of the experimental site were recorded by obtaining the composite soil samples from 0-15 cm depth. The soil texture of experimental plots was silty loam with a slightly acidic PH (5.16). The soil was with 0.13 Kg/ha Nitrogen, 45.66 Kg/ha Phosphorous, and 198 Kg/ha Potassium. The organic matter of the soil was 2.5 Kg/ha.

The average maximum temperature was 36.49$^0$C and the average minimum temperature 27.87 $^0$C was recorded during experimentation. The average annual rainfall of the study area was 307.31 mm during the entire period of experiment. (Source: Weather and Climate- The Global historical Weather and Climate Data 2022).

### 2.3. Experimental Design and Treatments

The experiment was carried out in two factorial randomized block designs with six treatments and four replications. One factor contains two varieties namely; Ram Dhan and Sabitri Dhan. Other factor consists of three nitrogen levels; 100 Kg/ha, 120 Kg/ha, and 140 Kg/ha. The amount of nitrogen was split into four parts equally and applied as basal dose just after transplanting, tillering stage, panicle initiation stage, and heading stage.

The individual plot size was 3 m x 3 m. The 12-day-old seedling at the rate of one seedling per spot was transplanted on 2$^{nd}$ July 2022 in the puddled field at the spacing of 25 cm x 25 cm. One hundred forty-four seedlings were transplanted in each plot. The standard practices were followed for all agronomic operations during the whole growing cycle of the crop.

## 3. Agronomic Performance and Yield Data Collection

### 3.1. Days of Anthesis (80%) Flowering

The number of days from the effective seedling date to the 80% flowering date was recorded.

### 3.2. Flag Leaf Length and Flag Leaf Width

Flag leaf length, from the ligule to the tip of the blade was measured seven days after anthesis with a ruler. The widest portion of the flag leaf was measured seven days after anthesis with a ruler. Five representative samples per plot were taken and the average was recorded and analyzed.

### 3.3. Culm Length and Culm Diameter

Culm length was measured from ground level to the base of the panicle with the help of a ruler after flowering. Culm diameter was measured as the outer diameter of the basal portion of the main culm at the late reproductive stage with a vernier caliper. Five representative samples per plot were taken and the average was recorded and analyzed.

### 3.4. Tiller Number Per Hill

The total number of tillers per hill were counted within a period of after anthesis to near maturity. Five representative samples per plot were taken and the average was recorded and analyzed.

### 3.5. Panicle Number Per Hill and Panicle Length

The number of panicles per hill was counted at the early ripening stage. The length of the main axis of the panicle was measured from the panicle base to the tip with a ruler. Five representative samples per plot were taken and the average was recorded and analyzed.

### 3.6. Number of Primary Branches and Secondary Branches of The Panicle

Five representative samples per plot were taken and the average was recorded and analyzed.

### 3.7. Yield components

Sterility %, grain weight per panicle, thousand-grain weight, grain yield, straw yield, and harvest index were calculated. Five representative samples per plot were taken and the average was recorded and analyzed.

### 3.8. Statistical Analysis

The data were collected and recorded on MS Excel. The data were analyzed by using GenStat software and mean comparisons were done using LSD and DMRT at 0.05 level of significance.

## 4. Result and Discussion

### 4.1. Flag leaf length and flag leaf width

The Sabitri variety had a higher flag leaf length (27.08 cm) and flag leaf width (1.277 cm) compared to Ram (26.90 cm and 1.263 cm, respectively), although these differences were statistically similar. This similarity might be due to both varieties being improved varieties used in the research. Among the nitrogen levels, 100 kg/ha resulted in a longer flag leaf length compared to 120 kg/ha and 140 kg/ha. For flag leaf width, 120 kg/ha showed a wider value than 100 kg/ha and 140 kg/ha. However, the flag leaf length and width values were statistically similar across the 100 kg/ha, 120 kg/ha, and 140 kg/ha nitrogen levels. This lack of significant impact might be due to heavy nitrogen losses during the rainy season. Moreover, Wang, Zhang, Cai, & Wang [14] reported that the greatest nitrogen losses, accounting for 85.9–95.9% of the annual loss, occurred between June and September. Losses in June and July accounted for 46.0% of the total, while losses in August and September accounted for 41.9%. The strong effects of the interactions could be obscured by experimental error [15]; therefore, the non-significant differences in flag leaf length and width might be due to errors in the variation between nitrogen doses.

**Table 1** Effect of Nitrogen Level on Flag Leaf Characteristics.

| Treatments | Flag leaf length (c.m) | Flag leaf width width (c.m) |
|---|---|---|
| Variety | | |
| Ram | 26.90 | 1.263 |
| Sabitri | 27.80 | 1.277 |
| Sem (±) | 0.895 | 0.0512 |
| LSD (0.05) | 2.699 | 0.1543 |
| F- value | NS | NS |
| Nitrogen levels (kg ha-1) | | |
| 100 | 27.91 | 1.238 |
| 120 | 26.59 | 1.305 |
| 140 | 27.55 | 1.268 |
| Sem (±) | 1.097 | 0.0887 |
| LSD (0.05) | 3.306 | 0.1890 |
| F- value | NS | NS |
| CV% | 11.3 | 14.0 |
| Grand mean | 27.35 | 1.270 |

### 4.2. Culm Length and Culm Diameter

The culm length (90.07 cm) and diameter (6.58 mm) were greater in the Ram variety compared to Sabitri, but the differences were statistically similar. This similarity might be due to both varieties being improved varieties used in the research. The culm length was found to be longer (92.50 cm) at 120 kg/ha nitrogen compared to 100 kg/ha and 140 kg/ha, which were statistically similar (86.53 cm and 87.23 cm, respectively). However, the culm diameter values at 100 kg/ha, 120 kg/ha, and 140 kg/ha nitrogen levels showed non-significant results. Wang, Xin, Nai, & Zheng [16] reported that the percentage of N loss to the total N was 2.09% to 32.14% due to leaching; non-significant difference in flag leaf length and flag leaf width is might be due to heavy losses of nitrogen during rainy season, resulting less impact on culm length and culm diameter. Furthermore, Luo, et al [17] pointed out that leaching accounts for 56-71% of the total N loss and is the main mechanism of N loss.

**Table 2** Effect of Nitrogen Level on Culm Characteristics.

| Treatments | Culm length (c.m) | Culm diameter (m.m) |
|---|---|---|
| Variety | | |
| Ram | 90.07 | 6.58 |
| Sabitri | 87.44 | 6.35 |
| Sem (±) | 1.657 | 0.339 |
| LSD (0.05) | 3.531 | 0.722 |
| F- value | NS | NS |
| Nitrogen levels (kg ha-1) | | |
| 100 | 86.53 b | 6.78 |
| 120 | 92.50 a | 6.78 |
| 140 | 87.23 b | 6.03 |
| Sem (±) | 1.657 | 0.415 |
| LSD (0.05) | 3.531 | 0.884 |
| F- value | 0.01** | NS |

| | | |
|---|---|---|
| CV% | 4.6 | 12.8 |
| Grand mean | 88.75 | 6.47 |

### 4.3. Tiller Number Per Hill, 80% Flowering Days, Panicle Length

The tiller number per hill was found higher in Sabitri variety (20.63) in comparison to Ram Variety (26.33). The number of tillers per hill for both varieties, Nevertheless, becomes statistically similar. Dhungana, et al [18] reported that the Sabitri variety had a slightly higher tiller number than Ram Variety with a non-significant result. The maximum number of tillers was found at 140 kg/ha nitrogen level (22.28) than 100kg/ha (18.85) and 120 kg/ha (20.23) although they are statistically similar. Awan TH [19] also reported that a higher number of tillers were observed at higher levels of nitrogen, with the tillers increased proportionally to the increase in nitrogen levels.

The main heading (80% flowering) was found about one day earlier in Ram (86.92 days after transplanting) in comparison to the Sabitri variety (88.33 days after transplanting), but difference was statistically similar. This is because Ram Dhan is a medium-maturing varieties whereas Sabitri is a late-maturing variety [20]. Among the nitrogen levels, late flowering of rice was observed with the application of 140 kg/ha (88.25 days after transplanting). This is due to high nitrogen (N) fertilization, aimed at maximizing crop yield, commonly postpones flowering time (heading date in rice) and ripening [21].

The Sabitri variety had slightly longer length (2.66 cm) compared to Ram Dhan (26.33), although this difference was not significant. Dhungana, et al [18] also reported that panicle length of Sabitri variety was slightly longer (29.24ab) than Ram variety(29.03ab) which were statistically similar. This might be due to both varieties were improved. Among the nitrogen levels, 100 kg/ha had slightly higher value (27.04 cm) compared to 120 kg/ha (26.98) and 140 kg/ha (25.98), although the differences were statistically non-significant.

**Table 3** Tiller Number Per Hill, 80% Flowering Days, Panicle Length

| **Treatments** | **Tiller number per hill** | **80% flowering (Day after transplanting)** | **Panicle length (c.m)** |
|---|---|---|---|
| Variety | | | |
| Ram | 20.63 | 86.92 | 26.33 |
| Sabitri | 26.33 | 88.33 | 26.66 |
| Sem (±) | 1.969 | 1.188 | 0.369 |
| LSD (0.05) | 4.198 | 2.532 | 0.786 |
| F- value | NS | NS | NS |
| Nitrogen levels (kg ha-1) | | | |
| 100 | 18.85 | 87.62 | 27.04 |
| 120 | 20.23 | 87.00 | 26.98 |
| 140 | 22.28 | 88.25 | 25.98 |
| Sem (±) | 2.412 | 1.455 | 0.452 |
| LSD (0.05) | 5.141 | 3.100 | 0.963 |
| F- value | NS | NS | NS |
| CV% | 23.6 | 3.3 | 3.4 |
| Grand mean | 20.45 | 87.62 | 26.50 |

### 4.4. Number of Primary Branches, Secondary Branches of Panicle, Panicle Number Per Hill

The number of primary branches per panicle was not found to be statistically significant in either the Ram or Sabitri varieties (12.83 and 12.52, respectively). The Ram variety had a higher number of secondary branches (26.52) compared to Sabitri (23.85), but the difference between the two varieties was statistically similar.

Among the different levels of nitrogen, the application of 120 kg/ha showed a slightly higher number of secondary branches (26.00) compared to 100 kg/ha (24.95) and 140 kg/ha (24.60). However, the number of secondary branches was not statistically influenced by the application of different nitrogen levels. In the case of the number of primary branches per panicle, the nitrogen levels of 100 kg/ha, 120 kg/ha, and 140 kg/ha did not show statistically significant differences at the 5% level (12.98, 12.95, and 12.10, respectively)

The panicle number per hill was not found statistically significant in both Ram and Sabitri varieties (15.42 and 16.15 respectively). But Sabitri Dhan had greater number of panicles per hill than Ram variety. Similar result was also found by Dhungana, et al [18]. 140 kg/ha nitrogen application results high number of panicles per hill (16.75) than 100 kg/ha (15.12) & 120 kg/ha (15.47). The higher number of effective tillers with increased fertilizer dosage is due to enhanced tiller survival and improved crop growth. Samrath lal Meena [22] reported that a higher dose of nitrogen resulted in an increased number of effective tillers in rice. Similarly, Yosef Tabar [23] found that nitrogen fertilizer application significantly increased the number of tillers per square meter in rice at harvest (95 days after transplanting).

**Table 4** Effect of Nitrogen Level on Primary Branch, Secondary Branch, And Panicle Number Per Hill.

| **Treatments** | **Number of primary branches** | **Number of secondary branches** | **Panicle number per hill** |
|---|---|---|---|
| Variety | | | |
| Ram | 12.83 | 26.52 | 15.42 |
| Sabitri | 12.52 | 23.85 | 16.15 |
| Sem (±) | 0.406 | 1.512 | 0.681 |
| LSD (0.05) | 0.865 | 3.233 | 2.052 |
| F- value | NS | NS | NS |
| Nitrogen levels (kg ha-1) | | | |
| 100 | 12.98 | 24.95 | 15.12 |
| 120 | 12.95 | 26.00 | 15.47 |
| 140 | 12.10 | 24.60 | 16.75 |
| Sem (±) | 0.497 | 1.852 | 0.834 |
| LSD (0.05) | 1.060 | 3.497 | 2.513 |
| F- value | NS | NS | NS |
| CV% | 7.8 | 14.7 | 14.9 |
| Grand mean | 12.68 | 25.18 | 15.78 |

### 4.5. Sterility %, Grain Weight Per Panicle, Thousand Grain Weight

Sabitri exhibited a lower sterility percentage (15.8%) compared to the Ram variety (17.15%). However, the sterility percentage for both varieties was not significantly different at the 5% level. Among the nitrogen levels, 140 kg/ha resulted in a lower sterility percentage (14.6%) compared to 100 kg/ha (16.8%) and 120 kg/ha (18.5%). However, the differences in sterility percentage among the nitrogen levels were also non-significant. This is because nitrogen not only enhances rice yield but also reduces spikelet sterility. However, heavy nitrogen application increases tillering and the number of spikelets per plant, which can lead to a reduction in the number of viable pollen grains per anther, thereby increasing spikelet sterility. [24].

Grain weight per panicle was higher for the Ram variety (3.04 g) compared to Sabitri (2.92 g), although this difference was statistically insignificant. Among the different nitrogen levels, 100 kg/ha resulted in a slightly higher grain weight per panicle (3.16 g) compared to 120 kg/ha (3.12 g). The lowest grain weight per panicle was observed at 140 kg/ha nitrogen level (2.66 g), though the differences were not significant at the 5% level.

Thousand-grain weight was higher for the Ram variety (24.02 g) compared to Sabitri (23.30 g). This result, which was not statistically significant, is supported by research conducted by Dhungana, et al [18]. That research found thousand-grain weights of 22.4 g for Savitri and 22.2 g for Ram Dhan. Among the nitrogen levels, 140 kg/ha recorded the highest thousand-grain weight (24.21 g), which is higher than that of 100 kg/ha (23.16 g) and 120 kg/ha (23.61 g). This is because increased nitrogen application leads to a greater thousand-grain weight, as supported by Ashouri M and Amiri E [25] & Yosef Tabar [23]. Both the results for the varieties and nitrogen levels were statistically similar at the 5% level of significance.

**Table 5** Effect of Nitrogen Level on Sterility, Grain Weight Per Panicle and Thousand Grain Weight**.**

| Treatments | Sterility (%) | Grain weight (gm/panicle) | Thousand grain weight (gm) |
|---|---|---|---|
| Variety | | | |
| Ram | 17.15 | 3.04 | 24.02 |
| Sabitri | 15.8 | 2.92 | 23.30 |
| Sem (±) | 2.66 | 0.214 | 1.166 |
| LSD (0.05) | 5.67 | 0.262 | 1.428 |
| F- value | NS | NS | NS |
| Nitrogen levels (kg ha-1) | | | |
| 100 | 16.8 | 3.16 | 23.16 |
| 120 | 18.5 | 3.12 | 23.61 |
| 140 | 14.6 | 2.66 | 24.21 |
| Sem (±) | 3.26 | 0.262 | 1.428 |
| LSD (0.05) | 6.95 | 0.557 | 3.043 |
| F- value | NS | NS | NS |
| CV% | 39.2 | 17.6 | 12.1 |
| Grand mean | 16.6 | 2.98 | 23.66 |

### 4.6. Grain Yield, Straw Yield and Harvest Index

The grain yield was found higher for the Ram variety (2.76 t/ha) in comparison to Sabitri variety (2.70 t/ha). Dhungana, et al [18] also found that Ram Dhan had higher yield (5.25ab) than Sabitri Dhan (4.58abcd) at Bhojad, Chitwan, Nepal. The lowest grain yield was recorded at 100 kg/ha nitrogen level (2.53t/ha) and highest was found at 120 kg/ha nitrogen level (2.86 t/ha). But results were statistically similar at 5% level of significant.

The straw yield was observed higher (6.36 t/ha) for Ram variety than Sabitri (6.36 t/ha). Dhungana, et al [18] observed that Ram variety had higher straw yield (8.4bcde) in comparison to Sabitri variety (7.8cdefg). The highest straw yield was recorded at 100 kg/ha nitrogen level (6.70 t/ha) and the lowest was found 6.08 t/ha at 140 kg/ha nitrogen level. But the results were statistically similar at 5% level of significant.

The harvest index was recorded lower for the Sabitri variety (0.422) than for Ram (0.440). The highest harvest index was found at 140 kg/ha nitrogen level (0.478) and the lowest was observed at 100 kg/ha nitrogen level (0.389), although the result for both varieties and nitrogen levels were not statistically significant at 5% level of significance.

**Table 6** Effect of Nitrogen Level on Grain Yield, Straw Yield and Harvest Index.

| Treatments | Grain yield (t/ha) | Straw yield (t/ha) | Harvest index |
|---|---|---|---|
| Variety | | | |
| Ram | 2.76 | 6.36 | 0.440 |
| Sabitri | 2.70 | 6.34 | 0.422 |
| Sem (±) | 0.215 | 0.685 | 0.0337 |
| LSD (0.05) | 0.458 | 1.459 | 0.1015 |
| F- value | NS | NS | NS |

| | | | |
|---|---|---|---|
| Nitrogen levels (kg ha-1) | | | |
| 100 | 2.53 | 6.70 | 0.389 |
| 120 | 2.86 | 6.40 | 0.426 |
| 140 | 2.79 | 6.08 | 0.478 |
| Sem (±) | 0.263 | 0.839 | 0.0413 |
| LSD (0.05) | 0.561 | 1.787 | 0.1243 |
| F- value | NS | NS | NS |
| CV% | 19.3 | 26.2 | 27.1 |
| Grand mean | 2.73 | 6.40 | 0.439 |

## 5. Conclusion

The findings of this study indicate that the impact of different nitrogen levels on the agronomic performance of rice varieties Ram and Sabitri is not statistically significant across various measured parameters, including flag leaf characteristics, culm dimensions, tiller number, flowering days, panicle length, branches, sterility percentage, grain weight, and yields. The most significant findings were that Sabitri variety exhibited slightly longer flag leaves and culm lengths, while the Ram variety showed higher grain yield and straw yield.

These findings suggest that both rice varieties, being improved types, respond similarly to nitrogen levels, likely due to heavy nitrogen losses during the rainy season and the narrow range of nitrogen levels tested. The results imply that higher nitrogen levels do not necessarily translate into significant agronomic advantages under the given conditions. This study makes a valuable contribution to understanding the nuanced effects of nitrogen application on improved rice varieties, emphasizing the need for optimized nitrogen management strategies to enhance rice productivity. This work highlights the importance of considering environmental factors and specific varietal characteristics in fertilizer application protocols to maximize agricultural output effectively.

## Compliance with ethical standards

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### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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