

Effect of Reduced NPK Fertilizer Dosage and Peptide Application on Rice Yield (*Oryza sativa* L.)

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ABSTRACT: Sustainable rice production requires efficient nutrient management to maintain crop productivity while reducing dependence on inorganic fertilizers. This study aimed to evaluate the effects of reduced NPK fertilizer dosage and peptide application on the yield of rice (*Oryza sativa* L.). The experiment was conducted under field conditions using a Split-Plot Design arranged in a Randomized Complete Block Design (RCBD) with two factors. The main plot factor was the reduction of NPK fertilizer dosage, consisting of three levels: 0% (P0), 10% (P1), and 20% (P2) reduction from the recommended rate. The subplot factor was peptide application, consisting of no peptide application (Kt) and peptide application at 4 mL L⁻¹ (Kd). Each treatment combination was replicated six times, resulting in a total of 36 experimental units. The results showed that reducing the NPK fertilizer dosage by up to 20% did not significantly affect the number of grains per panicle or grain yield per hectare. The 10% reduction treatment produced the highest grain yield, reaching 10.10 ton ha⁻¹. Peptide application had a highly significant effect on increasing the number of productive tillers, grain weight per hill, and grain yield per hectare. Peptide application increased the number of productive tillers from 24.57 to 27.74 tillers hill⁻¹, grain weight per hill from 56.04 g to 67.13 g, and grain yield from 7.83 ton ha⁻¹ to 11.23 ton ha⁻¹. A significant interaction between reduced NPK fertilizer dosage and peptide application was observed only for panicle length. Overall, the results indicate that peptide application can maintain and even improve rice yield despite reduced NPK fertilizer inputs, thereby offering a promising strategy for enhancing fertilizer-use efficiency in sustainable rice cultivation.

KEYWORDS: rice yield, peptide, NPK fertilizer, rice productivity, *Oryza sativa* L..

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important food crops and plays a strategic role in supporting global food security, particularly in Asia. More than half of the Asian population relies on rice as a staple food, making sustainable rice production essential for ensuring food availability and socioeconomic stability. In Indonesia, rice serves not only as the primary source of carbohydrates but also as a major agricultural commodity that significantly contributes to the national economy and farmers' livelihoods. Therefore, increasing rice productivity in a sustainable manner remains one of the key priorities in agricultural development.

Rice production in Indonesia has faced several challenges in recent years, resulting in a decline in overall output. According to Statistics Indonesia (BPS, 2024), the national production of milled dry grain in 2024 was estimated at 52.15–52.48 million tons, representing a decrease of approximately 2.8–3.4% compared with 53.63–53.98 million tons produced in 2023. When converted into rice, production in 2024 was estimated at 30.25 million tons, approximately 2.7% lower than the 31.10 million tons recorded in the previous year. This decline was attributed to several factors, including climate change-induced rainfall variability, increasing pest and disease incidence, and a reduction in harvested area. These conditions highlight the need for effective cultivation strategies to maintain and enhance rice productivity.

One of the most critical factors determining rice production is proper nutrient management through fertilization. Fertilization provides essential nutrients required for plant growth, tiller formation, panicle development, and grain filling. NPK fertilizer is widely used in rice cultivation because it supplies the three primary macronutrients: nitrogen (N), phosphorus (P), and potassium (K). Nitrogen is essential for chlorophyll formation and vegetative growth, phosphorus plays a crucial role in energy transfer and root development, while potassium regulates enzyme activity, water balance, and grain formation. Consequently, NPK fertilizer has become a fundamental component of modern rice production systems.

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Despite its effectiveness in increasing crop productivity, the continuous application of NPK fertilizer at high rates may lead to several economic and environmental concerns. Excessive fertilizer use increases production costs, reduces nutrient use efficiency, and may contribute to soil degradation and environmental pollution. Furthermore, a considerable proportion of applied nutrients can be lost through leaching, volatilization, and fixation processes, thereby reducing fertilizer efficiency. Therefore, innovative approaches are required to improve nutrient use efficiency and reduce fertilizer inputs without compromising crop productivity.

One promising approach is the use of plant biostimulants. Biostimulants are substances or microorganisms that enhance plant growth and productivity by stimulating physiological processes, improving nutrient uptake efficiency, and increasing plant tolerance to environmental stresses. Unlike fertilizers, which primarily serve as nutrient sources, biostimulants function by optimizing biological and metabolic processes within the plant. Among the various types of biostimulants, peptides have recently gained considerable attention due to their potential benefits in crop production.

Peptides are organic compounds composed of two or more amino acids linked by peptide bonds. In plants, peptides act as signaling molecules involved in regulating growth, development, nutrient acquisition, and stress responses. Sánchez et al. (2020) reported that peptide application can improve nutrient uptake efficiency, stimulate plant metabolism, and enhance tolerance to both biotic and abiotic stresses. Consequently, peptides have emerged as promising biostimulants for improving crop performance and nutrient use efficiency.

Keratin Hydrolysate Peptide (KHP) is one of the peptide-based biostimulants that has shown considerable potential for agricultural applications. KHP is produced through the hydrolysis of keratin, resulting in bioactive peptides and amino acids that can be readily utilized by plants. Previous studies have demonstrated that peptide application can improve crop growth and yield by enhancing physiological processes and nutrient utilization efficiency. Lay et al. (2025) reported that the application of peptides at a concentration of 4 mL L⁻¹ produced the highest productivity in Robusta coffee compared with other concentrations. In addition, peptide-based biostimulants have been reported to improve crop yield and quality in various agricultural commodities.

Although the beneficial effects of peptides have been documented in several crops, information regarding their application in rice cultivation, particularly in combination with reduced NPK fertilizer rates, remains limited. This represents an important research gap because integrating peptide application with reduced NPK fertilization may provide a more efficient, economical, and environmentally sustainable cultivation strategy. By improving nutrient uptake efficiency and optimizing plant physiological processes, peptides may help maintain or even increase rice yield despite reductions in NPK fertilizer application.

Therefore, this study was conducted to evaluate the effects of reduced NPK fertilizer rates and peptide application on the yield of rice (*Oryza sativa* L.). The findings of this research are expected to provide scientific information regarding the potential of peptides as biostimulants for improving fertilizer use efficiency and supporting the development of sustainable rice production technologies.

RESEARCH METHOD

Research Design

This study employed a Split Plot Design arranged in a Randomized Complete Block Design (RCBD). The main plot factor was the reduction of NPK fertilizer rate from the recommended dosage (P), consisting of three levels:

P0 = Recommended NPK fertilizer rate (100%)

P1 = Recommended NPK fertilizer rate reduced by 10% (90%)

P2 = Recommended NPK fertilizer rate reduced by 20% (80%)

The subplot factor was peptide application (K), consisting of two levels:

Kt = Without peptide application

Kd = Peptide application at a concentration of 4 mL L⁻¹ of water

The combination of both factors resulted in six treatment combinations. Each treatment was replicated six times, resulting in a total of 36 experimental units.

Research Location and Time

The study was conducted from December 2024 to July 2025 at Subak Guama, Kekeran Hamlet, Selanbawak Village, Marga District, Tabanan Regency, Bali, Indonesia, located at an altitude of approximately 500 m above sea level. Quality analysis of harvested rice grains was carried out at the Food Analysis Laboratory, Faculty of Agricultural Technology, Udayana University.

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Tools and Materials

The tools used in this study included seed soaking containers, rulers, digital balances, hand sprayers, measuring cylinders, plastic bags, sample envelopes, Petri dishes, scissors, ovens, counters, stakes, stationery, and laboratory equipment.

The materials used included rice seeds of the **INPARI 16** variety, **Keratin Hydrolysate Peptide (KHP)**, Urea fertilizer, Phonska Plus (15-15-15) fertilizer, compost fertilizer, fungicides, insecticides, distilled water, and clean water.

Research Implementation

The research was conducted through the following stages:

1. Seed Preparation

Rice seeds were soaked in a Golden Grow (GG) solution at a concentration of 1 mL L⁻¹ for 24 hours. The seeds were subsequently incubated for 2–3 days until germination occurred.

2. Seedling Nursery

The germinated seeds were sown in a prepared nursery bed. Seedlings were maintained under standard nursery management practices until they were ready for transplanting into the experimental field.

3. Land Preparation

The experimental field was plowed and harrowed twice to achieve suitable soil conditions for planting. Experimental plots were then established according to the treatment arrangement specified in the research design.

4. Planting and Treatment Application

Rice seedlings were transplanted into the experimental plots according to the treatment layout.

Peptide was applied as a foliar spray at a concentration of 4 mL L⁻¹ at **15, 40, and 65 days after transplanting (DAT)**.

Fertilization was carried out using Urea and Phonska Plus fertilizers according to the designated treatment levels. The recommended fertilizer rate consisted of:

- a. Urea: 200 kg ha⁻¹
- b. Phonska Plus: 400 kg ha⁻¹

The fertilizer reduction treatments were applied according to the experimental treatments (0%, 10%, and 20% reduction from the recommended dosage).

5. Crop Maintenance

Routine crop management included irrigation, weed control, and integrated pest and disease management according to field conditions throughout the growing season.

6. Harvesting

Harvesting was conducted at approximately 115 days after planting when 90–95% of the grains had turned yellow and reached physiological maturity.

Observation Variables

The variables observed in this study included:

1. Number of Productive Tillers (tillers hill⁻¹)

The number of productive tillers was counted at harvest by recording all tillers that produced fully developed panicles. The average number of productive tillers per hill was calculated for each treatment.

2. Panicle Length (cm)

Panicle length was measured at harvest using a ruler from the base to the tip of the panicle. Measurements were taken from all sample panicles and averaged for each treatment.

3. Number of Grains per Panicle (grains)

The total number of grains per panicle, including both filled and unfilled grains, was counted after harvest. The average number of grains per panicle was calculated for each treatment.

4. Grain Weight per Hill (g)

Grain weight per hill was measured after harvest by weighing the grains obtained from each sample hill. The average grain weight per hill was calculated for each treatment.

5. Grain Yield (ton ha⁻¹)

Grain yield per hectare was calculated based on grain yield obtained from each experimental plot using the following equation:

$$\text{Grain Yield (ton ha)} = (\text{Grain Weight per Plot (kg)} / (\text{Plot Area (m}^2\text{)}) \times 10,000$$

The resulting value was converted into tons per hectare.

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Data Analysis

The collected data were analyzed using Analysis of Variance (ANOVA) based on the Split Plot Design within a Randomized Complete Block Design.

When significant treatment effects were detected at the 5% significance level, mean separation was performed using the **Least Significant Difference (LSD) test at the 5% level**. If a significant interaction occurred between factors, treatment means were further compared using **Duncan's Multiple Range Test (DMRT) at the 5% significance level**.

The results were presented in the form of tables and discussed based on the statistical analyses to evaluate the effects of reduced NPK fertilizer rates and peptide application on rice yield (*Oryza sativa* L.).

RESULTS

Significance of Research Results

The analysis of variance revealed that NPK fertilizer reduction significantly affected the number of productive tillers, panicle length, and grain weight per hill, while it had a highly significant effect on the number of unfilled grains per panicle. Peptide application exerted a highly significant effect on the number of productive tillers, number of filled grains per panicle, number of unfilled grains per panicle, grain weight per hill, grain yield per hectare, and weight of 1,000 grains. Furthermore, a significant interaction between NPK fertilizer reduction and peptide application was observed only for panicle length. In contrast, the number of grains per panicle was not significantly affected by either factor or their interaction. These results indicate that peptide application plays an important role in improving rice yield components and productivity, while the reduction of NPK fertilizer dosage can be implemented without substantially reducing yield performance under certain conditions.

Table 1. Significance of the Effects of Reduced NPK Fertilizer Dosage and Peptide Application on Rice Yield Components

No.	Observation Variable	NPK Reduction (P)	Peptide (K)	Interaction
1	Number of Productive Tillers (tillers hill ⁻¹)	*	**	ns
2	Panicle Length (cm)	*	ns	*
3	Number of Grains per Panicle (grains)	ns	ns	ns
4	Grain Weight per Hill (g)	*	**	ns
5	Grain Yield (ton ha ⁻¹)	ns	**	ns

Note:

ns = Not significant ($P > 0.05$)

* = Significant at $P < 0.05$

** = Highly significant at $P < 0.01$

P = Reduced NPK fertilizer dosage

K = Peptide application

1. Number of Productive Tillers

The results showed that both NPK fertilizer reduction and peptide application significantly affected the number of productive tillers. The highest number of productive tillers was recorded in treatment P1 (27.13 tillers hill⁻¹), while the lowest value was observed in P0 (25.60 tillers hill⁻¹). Peptide application significantly increased the number of productive tillers, with Kd producing 27.74 tillers hill⁻¹ compared with 24.57 tillers hill⁻¹ in Kt (Table 2).

Table 2. Effect of Reduced NPK Fertilizer Dosage and Peptide Application on Number of Productive Tillers

Treatment	Number of Productive Tillers (tillers hill ⁻¹)
P0	25.60 b
P1	27.13 a
P2	25.73 b
LSD (5%)	1.16
Kt	24.57 b
Kd	27.74 a
LSD (5%)	1.41

Note:

Means followed by the same letter within a column are not significantly different according to the LSD test at the 5% level.

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2. Panicle Length

A significant interaction was observed between NPK fertilizer reduction and peptide application on panicle length. The highest panicle length was obtained from the P1Kt combination (25.01 cm), whereas the lowest value was recorded in P2Kt (22.47 cm). Under the absence of peptide application (Kt), treatment P1 produced the longest panicles. In contrast, under peptide application (Kd), the highest panicle length was observed in P2 (24.15 cm) (Table 3).

Table 3. Interaction Effect of Reduced NPK Fertilizer Dosage and Peptide Application on Panicle Length (cm)

Treatment	P0	P1	P2
Kt	22.74 a	25.01 a	22.47 b
Kd	23.82 a	24.14 a	24.15 a
LSD (5%)	2.34		

Note: Means followed by the same letter are not significantly different according to the LSD test at the 5% level.

3. Number of Grains per Panicle and Grain Weight per Hill

The number of grains per panicle was not significantly affected by either NPK fertilizer reduction or peptide application. The highest value was observed in P0 (100.23 grains), whereas the lowest was found in P2 (93.56 grains). Peptide application produced a slightly higher value (97.58 grains) than the control treatment (94.65 grains).

Grain weight per hill was significantly affected by NPK fertilizer reduction and highly significantly affected by peptide application. The highest grain weight per hill among NPK treatments was recorded in P0 (64.34 g), while Kd produced a substantially higher grain weight (67.13 g) compared with Kt (56.04 g) (Table 4).

Table 4. Effect of Reduced NPK Fertilizer Dosage and Peptide Application on Yield Components of Rice

Treatment	Number of Grains per Panicle (grains)	Grain Weight per Hill (g)
P0	100.23 a	64.34 a
P1	94.56 a	63.41 a
P2	93.56 a	57.01 b
LSD (5%)	10.89	5.78
Kt	94.65 a	56.04 b
Kd	97.58 a	67.13 a
LSD (5%)	7.46	4.64

Note: Means followed by the same letter within a column are not significantly different according to the LSD test at the 5% level.

4. Grain Yield

NPK fertilizer reduction did not significantly affect grain yield or the weight of 1,000 grains. The highest grain yield was recorded in P1 (10.10 ton ha⁻¹), while the highest weight of 1,000 grains was also observed in P1 (30.66 g) (Table 5).

Table 5. Effect of Reduced NPK Fertilizer Dosage and Peptide Application on Grain Yield and Weight of 1,000 Grains

Treatment	Grain Yield (ton ha ⁻¹)
P0	9.27 a
P1	10.10 a
P2	9.23 a
LSD (5%)	1.38
Kt	7.83 b
Kd	11.23 a
LSD (5%)	1.30

Note: Means followed by the same letter within a column are not significantly different according to the LSD test at the 5% level.

DISCUSSION

This study evaluated the effects of reduced NPK fertilizer dosage and peptide application on the yield performance of rice (*Oryza sativa* L.). Rice productivity is largely determined by nutrient availability and the plant's ability to efficiently convert assimilates into yield components. Nitrogen, phosphorus, and potassium are essential macronutrients involved in vegetative

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growth, reproductive development, photosynthesis, and grain production. Meanwhile, peptides act as biostimulants that enhance nutrient-use efficiency, stimulate physiological processes, and improve plant growth and productivity (Kumar & Gupta, 2022).

The results demonstrated that reducing NPK fertilizer application by up to 20% of the recommended dosage did not significantly decrease rice yield. This finding was reflected in grain yield per hectare, which showed no significant differences among fertilizer treatments. The highest grain yield was obtained from the 10% reduction treatment (P1), reaching 10.10 ton ha⁻¹, while the 20% reduction treatment (P2) produced a comparable yield of 9.23 ton ha⁻¹. These results suggest that rice plants were able to maintain nutrient-use efficiency despite reduced fertilizer inputs. Similar findings have been reported by Effendi et al. (2023), who stated that increasing fertilizer rates beyond the optimum level does not necessarily result in proportional increases in crop productivity.

The number of productive tillers is one of the most important yield components because it directly determines the number of panicles produced per unit area. The present study showed that reduced NPK fertilizer dosage significantly affected the number of productive tillers. Treatment P1 produced the highest number of productive tillers (27.13 tillers hill⁻¹), whereas P0 produced the lowest value (25.60 tillers hill⁻¹). Peptide application exerted a highly significant effect by increasing the number of productive tillers from 24.57 tillers hill⁻¹ in the control treatment to 27.74 tillers hill⁻¹ in the peptide-treated plants. This increase indicates that peptide application promoted tiller survival and development until the reproductive stage, thereby increasing the potential number of panicles and final yield. According to Rochmad et al. (2021), productive tiller formation is strongly influenced by nutrient availability and efficient assimilate distribution throughout plant growth.

A significant interaction between reduced NPK fertilizer dosage and peptide application was observed for panicle length. The longest panicle was recorded in treatment P1Kt (25.01 cm), whereas the shortest panicle was observed in P2Kt (22.47 cm). The significant interaction suggests that the effect of peptide application on panicle development depended on the level of NPK fertilization. Panicle length is an important yield component because longer panicles generally possess a greater capacity to support grain formation. Khasanah (2021) reported that panicle development is closely associated with assimilate availability during the reproductive phase, particularly during panicle initiation and differentiation.

The number of grains per panicle was not significantly affected by either reduced NPK fertilizer dosage or peptide application. The values ranged from 93.56 to 100.23 grains per panicle across treatments. This result indicates that grain number per panicle was relatively stable and was likely controlled more strongly by genetic factors than by the nutrient management practices applied in this study. Similar observations were reported by Rochmad et al. (2021), who noted that grain number per panicle is generally less responsive to environmental and management factors than other yield components.

Grain weight per hill was significantly affected by reduced NPK fertilizer dosage and highly significantly affected by peptide application. The highest grain weight per hill was obtained under P0 (64.34 g), whereas the lowest was observed under P2 (57.01 g). Peptide application increased grain weight per hill from 56.04 g to 67.13 g. Grain weight per hill represents the accumulation of yield at the individual plant level and reflects the effectiveness of assimilate production and partitioning during grain development. The increase in grain weight per hill suggests that peptide application improved nutrient utilization and physiological efficiency, resulting in greater biomass allocation to grain production (Tan et al., 2024).

The increase in grain weight per hill contributed to grain yield per hectare. Although reduced NPK fertilizer dosage did not significantly affect grain yield, the highest yield was achieved by the P1 treatment (10.10 ton ha⁻¹). This result indicates that a reduction of NPK fertilizer by up to 20% can maintain rice productivity at a level comparable to the recommended fertilization rate. Such findings support the concept of sustainable nutrient management, which aims to optimize fertilizer use while minimizing production costs and environmental impacts (Jelita et al., 2025).

In contrast, peptide application significantly increased grain yield per hectare. Grain yield increased from 7.83 ton ha⁻¹ in the untreated plants to 11.23 ton ha⁻¹ in the peptide-treated plants. This substantial improvement demonstrates the effectiveness of peptides as biostimulants capable of enhancing plant physiological performance and nutrient-use efficiency. According to Tan et al. (2024), biostimulants can improve photosynthetic activity, assimilate translocation, and overall crop productivity, thereby contributing to higher yields under reduced fertilizer inputs.

Overall, the results indicate that reducing NPK fertilizer dosage by up to 20% did not significantly reduce rice yield. Peptide application enhanced important yield components, particularly the number of productive tillers, grain weight per hill, and grain yield per hectare. Furthermore, a significant interaction between reduced NPK fertilizer dosage and peptide application was observed for panicle length. These findings suggest that peptide application can serve as an effective strategy to improve fertilizer-use efficiency while maintaining or enhancing rice productivity. Therefore, the integration of reduced NPK fertilizer application with peptide supplementation has considerable potential for supporting sustainable rice production systems.

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CONCLUSION

Based on the results of this study on the effects of reduced NPK fertilizer dosage and peptide application on the yield of rice (*Oryza sativa* L.), the following conclusions can be drawn:

1. Reducing the NPK fertilizer dosage by up to 20% of the recommended rate did not significantly decrease rice yield. The 10% reduction treatment (P1) produced the highest grain yield of 10.10 ton ha⁻¹, although it was not significantly different from the other fertilizer treatments. Reduced NPK fertilizer dosage significantly affected the number of productive tillers, panicle length, and grain weight per hill.
2. Peptide application at a concentration of 4 mL L⁻¹ had a highly significant effect on several rice yield components. Peptide application increased the number of productive tillers, grain weight per hill, and grain yield per hectare. The highest grain yield was obtained from the peptide treatment (Kd), reaching 11.23 ton ha⁻¹.
3. A significant interaction between reduced NPK fertilizer dosage and peptide application was observed for panicle length. However, no significant interaction was detected for the other yield variables. In general, peptide application was able to maintain and even improve rice yield despite the reduction in NPK fertilizer dosage.
4. The use of peptides as biostimulants has considerable potential to improve NPK fertilizer-use efficiency and may serve as an alternative technology for more efficient, economical, and sustainable rice cultivation systems.

ADVICE

Based on the findings of this study, the application of peptides at a concentration of 4 mL L⁻¹ is recommended in rice cultivation because it has been proven to improve important yield components and overall crop productivity. Furthermore, reducing the NPK fertilizer dosage by 10–20% of the recommended rate can be combined with peptide application to enhance fertilizer-use efficiency without reducing rice yield.

Further studies are recommended to evaluate the effectiveness of peptide application under different rice varieties, soil conditions, and environmental conditions. Such studies would contribute to the development of broader and more reliable recommendations regarding peptide utilization and optimal NPK fertilizer management for sustainable rice production.

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