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

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Abstract

Rice (*Oryza sativa* L.) is a strategic commodity in Indonesia that produces rice and is consumed by the community, so rice production needs to be increased. This study aims to determine the effect of reducing the dose of NPK fertilizer and the application of Keratin Hydrolyzate Peptide (peptide) on the yield and yield components of rice plants. The study used a split plot Randomized Group Design (RAK) with 2 factors and 6 replications. The first factor as the main plot was a reduction in the dose of NPK fertilizer (P) consisting of 3 treatment levels, namely P0 (fertilization according to the recommended dose or the farmer's method), P2 (recommended dose reduced by 20%), and P4 (recommended dose reduced by 40%). The second factor as a subplot is the application of Keratin Hydrolyzate Peptide (K) consisting of 2 levels, namely K_t (no peptide) and K_d (peptide). This research was conducted from January to June 2024. The results showed that the interaction between the reduced dose of NPK fertilizer and the provision of peptides had a very significant effect on the variables of grain yield of hectare Reduction of NPK dosage up to 20% (P_2) gave weight per 1.000 grain (23.59 g), panicle length (26.48 cm), plant height (115.38 cm), and leaf color (4.40 BWD units). Peptide application can provide the number of filled panicles (20.99 pieces), leaf color (4.41 BWD units), total tillers (29.21 stems), number of productive tillers (24.45 stems), and weight per 1.000 rice (14.68 g). Reducing the dosage of NPK fertilizer by 20% and applying peptides can be the latest solution for farmers to increase the productivity of rice plants.

Keywords: NPK Dosage; Rice; Peptide; Yield

1. Introduction

Rice (*Oryza sativa* L.) is a strategic commodity in various countries, especially in Indonesia, which can produce rice and is consumed by the community. The people's need for rice as the main food continues to increase every year in accordance with the rate of population growth [1]. The high consumption of rice in Indonesia is inseparable from the nutritional content in the form of carbohydrates, protein, fat, fiber, and vitamins in rice which are certainly beneficial for the human body [2].

Based on data from the Central Statistics Agency (BPS) [3], rice production in 2023 for food consumption by the Indonesian population is estimated to be around 30.90 million tons, or a decrease of 645.09 thousand tons when compared to rice production in 2022 which amounted to 31.54 million tons. Meanwhile, the Ministry of Agriculture (MOA) targets rice production in 2024 to reach 35 million tons. Therefore, rice production needs to be increased to meet the food needs of the community for rice.

Currently Indonesia still often faces food problems and challenges such as global climate efforts that cause the conversion of paddy fields and Indonesia's specific land conditions from irrigated rice fields, rainfed, dry land, lebak swamps, and tidal swamps to housing and industrial areas, resulting in a decrease in rice productivity [4]. The

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conversion of agricultural land that continues to occur in Bali is a threat to food security on the Island of the Gods whose population continues to grow so that food needs increase

Changes in agricultural land use pose a threat to achieving food security, especially rice. Efforts to increase rice production and productivity can be done through improved cultivation technology, one of which is through fertilization. Fertilizer is a material with micro and macro nutrients that are needed by a plant [5]. Farmers in Indonesia prefer to use inorganic fertilizers because inorganic fertilizers are easy to find and easy to use [6]. One of the inorganic fertilizers used for rice plants is NPK fertilizer. This NPK fertilizer is a compound fertilizer that contains macro nutrients N, P, and K which can add nutrients in the soil and is more quickly available so that it can be absorbed directly by plants after dissolving in water. The continuous use of chemical fertilizers can have a negative impact on the environment. An alternative solution that can be used to reduce farmers' dependence on chemical fertilizers is to reduce the dose of NPK fertilizer and utilize organic fertilizers in rice cultivation.

One of the products that can be used is Keratin Hydrolyzate Peptide, hereafter commonly referred to as peptides. Through new and innovative research, peptides are one way of developing next-generation bio-based products for certain crops, increasing stress tolerance, optimizing nutrient use efficiency and resistance to extreme climates. Peptides made from environmentally friendly poultry feathers and fish scales contain amino acids that act as signal regulators to optimize plant nutrient utilization under variable climatic conditions through enhanced nutrient uptake and assimilation, plant root formation and repair, enhanced photosynthetic assimilation and plant resistance to extreme climates [7]. An example of the research results of CH Biotech R&D Co., Ltd (2023), namely lettuce growth trials with the application of peptides sprayed on the leaves so as to encourage the growth of lettuce above the ground which shows that peptides can increase lettuce yield, then peptides can increase the color rate and increase anthocyanin content in grape plants, and increase leaf area and chlorophyll content in tomato plants in greenhouses.

Reducing the dosage of NPK fertilizer and applying peptides can be an effective strategy to optimize the growth of yield components and yield of rice plants. By using peptides, plants can utilize available nutrients more efficiently, thus reducing dependence on high fertilizer doses. It is important to observe the correct dosage so as not to cause nutrient imbalances that can be detrimental to the plant.

Based on information through personal communication with representatives of CH Biotech R&D Co., Ltd (2023), the optimum concentration of peptides for rice plants is 2 ml/L and the application is done when the formation of tillers, early bunting, and early seed filling. Therefore, this study was conducted to determine the effect and effect of reducing the appropriate dose of NPK fertilizer and peptide application on the yield components and yield of rice plants.

2. Materials and methods

2.1. Materials

The tools used in this research are tractors, hoes, trays, buckets or basins, scissors, meters, hand sprayers, clurit or sickles, stakes, scales, sieves, grinding machines, screw micrometers, ovens, measuring cups, PPE, LUX meters, relative water content (KAR) measuring instruments, SPAD chlorophyll meters, stationery and cameras.

The materials used in this research are rice seeds of Inpari IR Nutri Zinc variety, Urea, Phonska Plus 15-15-15, Compost Fertilizer, Tanivit Leaf Fertilizer, Fungicide: Antracol 70 wp, Filimax 650 sc, Wendry 75 wp (M2U). Insecticides (Klensect 200 EC, Dangke 40 wp, Winder 25 wp, Lamdador 50 EC CyperMAX 100 EC, Trisula 450 SL (systemic)), and Keratin Hydrolyzate Peptide (Peptide) from CH Biotech R&D Co. Ltd. Taiwan (2023).

2.2. Methods

The research was conducted at Subak Jaka, Kukuh Village, Marga District, Tabanan Regency with an altitude of ± 800 m above sea level. and at the Agronomy and Horticulture Laboratory, Faculty of Agriculture, Udayana University from January to June 2024. The research design used was randomized group split plot design with 2 factors and 6 replications. The first factor as the main plot was the reduced dose of NPK fertilizer (P) consisting of 3 levels, namely: P_0 = Fertilization according to the recommended dose or farmer's method, P_2 = Recommended dose reduced by 20%, P_4 = Recommended dose reduced by 40%. The second factor is the application of Keratin Hydrolyzate Peptide (K) consisting of 2 levels, namely: K_t = with Keratin Hydrolyzate Peptide, K_d= no Keratin Hydrolyzate Peptide. The observation variables consisted of yield per hectare, 1.000 grain weight, number of filled grain per panicle, number of grain per panicle, number of productive tillers, relative leaf content, leaf chlorophyll, plant height, panicle length, leaf color, number of filled panicles, total number of tillers, number of productive tillers, weight per 1.000 rice

The research started from land preparation and plot arrangement, where three main plots (P_0, P_2, and P_4) were selected based on uniform soil conditions and randomized before tilling using a mini tractor. Each plot was divided into six replications, further split into two sub-plots, totaling 32 sub-units. Seedlings were transplanted following local farming practices, and fertilization was applied based on treatment levels: P_0 (100% NPK), P_2 (80% NPK), and P_4 (60% NPK), with specific doses of Phonska and Urea at 5, 30, and 45 days after transplanting (DAT). Peptide application was conducted at 15, 40, and 65 DAT, alongside additional fertilizers such as Tanivit foliar fertilizer (3.5 tbsp/L) and compost (10 tons/ha). Crop maintenance, including irrigation, weeding, and pest control, was carried out intensively according to standard practices. Harvesting took place at around 100 DAT when the rice reached physiological maturity, indicated by grain color changes and the cessation of photosynthate transfer. The harvested rice was categorized based on treatments for further evaluation of grain quality.

3. Results and discussion

The results of the analysis of variance showed that the interaction between the reduced dose of NPK fertilizer and the application of Keratin Hydrolyzate Peptide had a very significant effect on the variable grain yield per hectare, on other variables the interaction showed no significant effect. The single factor of reducing the dose of NPK fertilizer had a very significant effect on the variable of grain yield per hectare, had a significant effect on the variable of relative water content of leaves, the number of total tillers, the number of filled panicles, the number of filled grains per panicle, grain yield per clump, had no significant effect on plant height, panicle length, leaf color, leaf chlorophyll content, the number of productive tillers, the number of grains per panicle, and weight per 1.000 grain and weight of 1.000 rice. The single factor of Keratin Hydrolyzate Peptide application showed no significant effect on all observation variables except for grain yield per hectare which showed a significant effect.

Table 1 Two-way table of the treatment of reduced dose of NPK fertilizer (P) with Keratin Hydrolyzate Peptide (K) on plant height, leaf chlorophyll content, leaf relative water content, leaf color, and panicle length.

Treatment	Plant Height (cm)	Leaf Chlorophyll Content (SPAD)	Leaf Relative Water Content (%)	Leaf Color (BWD Unit)	Panicle Length (cm)
Reduction of NPK Fertilizer Dosage					
P_0	113.04 a	40.50 a	72.05 a	4.35 a	24.01 a
P_2	115.38 a	40.38 a	64.57 b	4.40 a	24.62 a
P_4	113.01 a	41.11 a	72.57 a	4.37 a	23.48 a
5% LSD	4.02	1.12	6.68	0.14	1.20
Peptide Administration					
K_t	113.91 a	40.78 a	70.47 a	4.33 a	24.17 a
K_d	113.71 a	40.54 a	69.10 a	4.41 a	23.90 a
5% LSD	2.95	0.64	4.89	0.10	0.53

(P_0): No reduction in NPK dosage; (P_2): 20% NPK dose reduction; (P_4): 40% NPK dose reduction; (K_t): Without peptide administration; (K_d): Peptide treatment. Values in the same vertical columns followed by one or more of the same letters were not significantly different at the 0.05 significance level according to the Least Significant Difference (LSD) test.

Table 2 Two-way table of the treatment of reduced dose of NPK fertilizer (P) with Keratin Hydrolyzate Peptide (K) on number of productive tillers, number of grains in panicle, number of filled grains in panicle, weight of 1000 grains, 1000 rice weight.

Treatment	Number of Productive Tillers (stem)	Number of Grains in Panicle (grain)	Number of Filled Grains in Panicle (grain)	Weight of 1000 Grains (g)	1000 Rice Weight (g)
Reduction of NPK Fertilizer Dosage					
P_0	24.42 a	110.19 a	92.32 a	23.14 ab	14.90 a
P_2	23.19 a	106.88 a	90.24 a	23.59 a	14.72 a
P_4	23.41 a	99.89 a	76.38 b	21.93 b	14.11 a
5% LSD	1.67	13.22	12.44	1.51	0.86
Peptide Administration					
K_t	22.90 a	107.43 a	87.65 a	22.99 a	14.48 a
K_d	24.45 a	103.88 a	84.98 a	22.78 a	14.68 a
5% LSD	1.62	11.59	10.81	0.77	0.56

(P_0): No reduction in NPK dosage; (P_2): 20% NPK dose reduction; (P_4): 40% NPK dose reduction; (Kt): Without peptide administration; (Kd): Peptide treatment. Values in the same vertical columns followed by one or more of the same letters were not significantly different at the 0.05 significance level according to the Least Significant Difference (LSD) test.

Table 3 Two-way table of the treatment of reduced dose of NPK fertilizer (P) with Keratin Hydrolyzate Peptide (K) on number of filled panicles, total number of seedlings, grain yield of clump.

Treatment	Number of filled panicles (fruit)	Total number of seedlings (stems)	Grain Yield Per Clump (g)
Reduction of NPK Fertilizer Dosage			
P_0	21.72 a	31.92 a	55.62 (7.44) a
P_2	19.75 c	27.69 b	49.72 (7.17) a
P_4	20.03 b	26.94 c	43.76 (6.64) b
5% LSD	1.46	3.41	0.60
Peptide Administration			
K_t	20.01 a	28.49 a	49.43 (7.04) a
K_d	20.99 a	29.21 a	49.97 (7.13) a
5% LSD	1.79	2.05	0.50

(P_0): No reduction in NPK dosage; (P_2): 20% NPK dose reduction; (P_4): 40% NPK dose reduction; (Kt): Without peptide administration; (Kd): Peptide treatment. Values in the same vertical columns followed by one or more of the same letters were not significantly different at the 0.05 significance level according to the Least Significant Difference (LSD) test.

Table 4 Interaction between Reduced Dosage of NPK Fertilizer (P) and Application of Keratin Hydrolyzate Peptide (K) on Grain Yield Variables Per Hectare.

Treatment	P0	P2	P4
K_t	5.80 b	5.53 bc	5.15 cd
K_d	5.89 b	6.87 a	4.90 d

Numbers followed by the same letter indicate that they are not significantly different in the 5% BNT test.

3.1. Effect of Reduced Doses of NPK Fertilizer on Yield Components and Rice Yields

In the single factor of reducing the dose of NPK fertilizer, reducing the dose of NPK fertilizer by 20% of the recommended dose (P_2) on the observation variable of plant height showed the highest plant height results (115.38 cm), but the P_2 treatment was not significantly different from all treatment levels. Plant height can increase the ability of plants to produce photosynthate, because leaves are the main organ that carries out photosynthesis which will compose plant biomass [8]. The photosynthate will be translocated to vegetative and generative organs that need it. During the vegetative phase, the plant prepares its various organs, especially the leaves, to be better able to enter the generative phase, with the increase in radiation that can be absorbed by the leaves in this period will be used by plants to form generative organs, with the formation of the main sink, namely grain. Plant height indicates the large proportion of crown or biomass as a source. The crown is part of the plant that plays a role in the photosynthesis process, the more photosynthate produced, the greater the effect on grain weight [9]. P_2 (recommended dose of NPK which is reduced by 20%) has the highest grain weight of 23.59 g, which is not significantly different from the P_0 treatment (fertilization according to the recommended dose) which is 23.14 g. The P_2 treatment is significantly different from the P_0 treatment. The P_2 treatment was significantly different from P_4 (fertilization treatment with the recommended dose of NPK reduced by 40%) which was 21.93g. The weight of 1000 grains is positively correlated and in the same direction with the variable grain yield per hectare, which means that grain yield per hectare is influenced by the weight of 1000 grains. The weight of 1000 grains is strongly influenced by the size and shape of the grain [10], the larger the grain size, the greater the weight of the grain produced, and vice versa, a small grain size will produce a light grain weight. The heavier the grain and the weight of 1,000 grains will provide a significant correlation to plant yield [11]

In the single factor of reducing the dose of NPK fertilizer, the P_0 or control treatment gave the highest results on several observation variables but showed results that were not significantly different, such as the number of productive tillers, the number of grains per panicle, and the number of filled grains per panicle. In the P_2 treatment, the best leaf color results were 4.40 BWD units, which were not significantly different from P_4 (4.37 BWD units) and P_0 (4.35 BWD units). Leaf color in P_2 shows sufficient chlorophyll content due to optimal nitrogen availability. The level of leaf greenness is directly correlated with nitrogen content and photosynthetic efficiency, which ultimately affects crop yield [12]. Leaf chlorophyll content was not significantly different between treatments, with P2 (40.38 SPAD units) close to P0 (40.50 SPAD units) and P4 (41.11 SPAD units). Leaf KAR showed a lower value in P2 (64.57%) compared to P0 (72.05%), while P4 had the highest value (72.75%). In P_2, sufficient nitrogen supports photosynthetic efficiency and seed filling, so that plant energy is directed to generative growth rather than maintaining tissue hydration. The treatment of reducing the dose of NPK fertilizer to 20% (P_2) gave results on panicle length variables that tended to be the highest (24.62 cm), not significantly different from all treatments (P_0 and P_4).

3.2. Effect of Peptide Application on Yield Components and Yield of Rice

In the single factor of peptide application, the number of productive tillers gave higher results with a value of 24.45 stems, significantly different from the treatment not given peptide (K_t) which had a result of 22.90 stems. The total number of tillers K_d (29.21 stems) tended to be higher than the treatment not given peptide, K_t (28.49 stems). The application of organic fertilizer can increase the number of tillers and the number of productive tillers [13]. Variable grain yield per clump K_d (49.97 g) was not significantly different from K_t (49.43). Higher grain yield per clump contributed to an increase in overall grain yield [14]. Weight per 1,000 rice in treatment K_d (14.68 g) was not significantly different from K_t (14.48 g). The peptide did not significantly change the weight per 1,000 rice, indicating that rice grain size is more influenced by genetic factors and water availability during the grain filling period, however, rice quality tended to be better, with a denser texture in plants treated with the peptide. The number of filled panicles K_d (20.99) was not significantly different from K_t (20.01). Leaf color K_d (4.41 BWD units) was significantly different from K_t (4.33 BWD units). Over-application of nitrogen (N) fertilizer causes the plants to turn dark green, lodging easily [15] so that plants are more susceptible to pests and diseases [16]. Therefore, organic fertilizer recommendations are very important. CH Biotech states that the provision of peptides can increase the plant's defense system, so that peptides with their antimicrobial activity can increase plant resistance when exposed to pest and disease attacks due to excessive N fertilizer.

The provision of peptides (Kd) gives results that tend to be high and shows results that are not significantly different in several variables because peptides have a role as a biofertilizer, which contains organic nitrogen that can be used directly by plants and increases the activity of soil microbes that play a role in the decomposition of organic materials and the release of nutrients. . As a biostimulant, peptides play a role in increasing plant tolerance to environmental stress as well as stimulating root growth and increasing photosynthetic efficiency. Peptides also have a role as bioprotectants, which increase plant resistance to pathogen attack and environmental stress through increased synthesis of antioxidant compounds and strengthening of plant cell walls.

3.3. Interaction between Reduced Dosage of NPK Fertilizer (P) and Application of Keratin Hydrolyzate Peptide (K) on Grain Yield Variables Per Hectare

The interaction treatment (recommended dose reduced by 20% and peptide application) gave the highest rice grain yield per hectare (6.87 tonnes/ha) which was significantly different from the P4Kd treatment, namely the recommended dose of NPK fertilizer reduced by 40% + peptide application which had a low grain yield per hectare with a value of 4.90 tonnes/ha. These results indicate that the provision of peptides supports better nutrient utilization when the fertilizer dose is reduced, in line with research [17] which shows the interaction between inorganic fertilizers and organic materials can provide optimal results through increased fertilizer efficiency and nitrogen reduction. Thus, the decrease in rice productivity in the P4Kd combination treatment was caused by nutrient deficiencies of Nitrogen (N), Phosphorus (P), and Potassium (K) in rice. Peptides are not able to fully cover the deficiency of NPK fertilizer up to 40% so that rice plants cannot reach their maximum production potential. Lack or excess of nutrients given to plants results in the photosynthesis process not running effectively and the photosynthate produced is reduced, causing the amount of photosynthate translocated to rice grains to be reduced [18]. The treatment of reducing the dose of NPK fertilizer by 20% and giving peptides showed results that were not significantly different from the treatment without reducing the dose of NPK fertilizer and giving peptides. This means that by reducing the dose of NPK fertilizer by 20% and giving peptides can achieve grain yield per hectare which is comparable to the recommended dose that is commonly used by farmers. Rice plants are still able to produce optimal yields and do not reduce the quality of yields even though the fertilizer dose is reduced. This reduction in fertilizer dosage will reduce the cost of purchasing NPK fertilizer and the cost of rice production, thus helping farmers to save on rice cultivation costs.

4. Conclusion

Reduction of NPK fertilizer dosage to 20% (P_2) did not significantly reduce yield components and rice yield. Peptide application did not show significant differences in yield components and showed a significant interaction in increasing yield, especially when fertilizer was reduced. The treatment of 20% reduced dose of NPK fertilizer with peptides (P_2K_d) produced the highest grain yield per hectare, which was 6.87 tonnes/ha, higher than P_0K_d (fertilization at the recommended dose or farmers' method with peptides) which gave a yield of 5.89 tonnes/ha, thus an increase of 16.64%. At a 40% reduction in NPK fertilizer dosage and peptide application (P_4K_d), the yield decreased to 4.90 tonnes/ha, indicating that a 40% reduction in NPK fertilizer dosage could not achieve maximum rice production potential.

Compliance with ethical standards

Disclosure of conflict of interest

There are no impact interests that need to be disclosed

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