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Research Article

Growth and yield of several rice varieties on alluvial soil using N, P, and K fertilizers

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ABSTRACT

Adaptive varieties and N, P, and K fertilization can increase rice productivity. The study aimed to determine the effect of N, P, and K fertilizer dosages on the growth and yield of several rice varieties on alluvial soil. The research was conducted in Kubu Raya Regency, West Kalimantan, from March to October 2023. The method used a factorial randomized complete block design with three replications. The first factor was rice varieties (Argo Pawan, Bima Saputra, Inpari 43, Padang, and Tropiko). The second factor was N, P, and K fertilization (150 kg N ha^{-1}+ 100 kg P_2O_5 ha^{-1} + 100 kg K_20 ha^{-1}; 300 kg N ha^{-1} + 200 kg P_2O_5 ha^{-1} + 200 kg K_20 ha-1; 450 kg N ha^{-1} + 300 kg P_2O_5 ha^{-1} + 300 kg K_20 ha^{-1}). The Tropiko variety had the highest plant height compared to other varieties. The Inpari 43 variety produced the highest maximum number of tillers. Furthermore, the Inpari 43 and Tropiko varieties were the best treatments for producing the number of productive tillers and grain weight per plot. The N, P, and K fertilizer dosage of 300 kg N ha^{-1} + 200 kg P_2O_5 ha^{-1} + 200 kg K_20 ha^{-1} was the best treatment in producing growth and yields of rice plants based on the variables of maximum number of tillers, number of productive tillers, and grain weight per plot.

Keywords: adaptive varieties; rice productivity; soil fertility

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INTRODUCTION

The increase in the productivity of rice plants is one of the important strategies that the Government of West Kalimantan is focused on to meet regional food needs and support national food security. Based on data from the BPS (2023), the production of rice on the national scale in Indonesia in 2022 reached 54,748,977 tons of Dry Unhusked Rice (DUR) with a productivity of 5.24 tons of DUR per hectare. Based on these production data, West Kalimantan have rice production of 731,226 tons of DUR with a productivity of 3.02 tons of DUR per hectare. The data shows that the level of productivity in West Kalimantan is still far below the national productivity figure, so efforts are needed to support national food security and increase rice productivity in West Kalimantan

The rice needs of the people in West Kalimantan reach an average of 533,628 tons per year, while rice production data in West Kalimantan in 2022 was 432,587 tons BPS (2023). The data above shows that rice production in West Kalimantan has yet to meet public demand, and rice productivity in West Kalimantan is still below national-scale productivity. Hence, efforts must be made to increase rice productivity by applying appropriate cultivation technology.

Rice cultivation land in West Kalimantan is generally rice fields on alluvial soil with a harvest area of 218,468.40 hectares (BPS, 2021). The conditions of rice fields with alluvial soil types, which are limiting factors for the growth of rice plants, are quite high clay content, low cation exchange capacity, and very low nutrient availability. Other factors that cause low rice productivity in West Kalimantan include the suitability of the

plant-growing environment for the rice varieties being cultivated, such as the suitability of climatic conditions and the presence of pest and disease stress. According to the research of Mahendra et al. (2024), NPK fertilization of 450 kg ha^{-1} can support increased rice productivity in rice fields. Furthermore, the research of Rijaidinsyah et al. (2024) showed that the best use of NPK fertilizer to increase rice productivity in rice fields is with a dose of 300 kg ha^{-1}.

The use of rice varieties that are adaptive to the plant-growing environment can be one component of cultivation technology essential to support high productivity. According to Hudoyo and Nurmayasari (2018), intensification efforts using superior varieties are one of the main components of rice cultivation technology that increase productivity. The advantages of using rice varieties in maintaining productivity are that they are adaptive to drought stress and acid land conditions, tolerant to aluminum poisoning, and resistant to pest and disease stress (Koesrini et al., 2020; Chanifah et al., 2021; Herdiyanti et al., 2021).

Regulating nutrient input through fertilizing N, P, and K into the soil is important in maximizing productivity for each rice variety. Sufficient availability of N, P, and K nutrients for rice plants can support plant metabolic processes (Mpapa, 2016). According to Sukmawati et al. (2021), applying NPK fertilizer to rice plants can maximize the function of photosynthesis in plants. According to Sitanggang et al. (2018), plant growth and development needs the nutrients N, P, and K in balanced amounts. Therefore, applying N, P, and K fertilizers at optimum doses can be crucial in achieving maximum rice yields (Li et al., 2015).

The study aimed to determine the effect of N, P, and K fertilizer dosages on the growth and yield of several rice varieties on alluvial soil.

MATERIALS AND METHODS

The research was conducted in Rasau Jaya 3 Village, Kubu Raya Regency, West Kalimantan. The research period was from March to October 2023. The study was carried out on rice fields with alluvial soil types. Nutrients N, P_2O_5, and K_2O were sourced from Urea fertilizer, SP-36 fertilizer, and KCl fertilizer. The research method used a factorial randomized complete block design with three replications. The first factor was the use of rice varieties with five levels (Argo Pawan variety, Bima Saputra variety, Inpari 43 variety, Padang variety, and Tropiko variety). The second factor was N, P, and K fertilization with three levels (150 kg N ha^{-1} + 100 kg P_2O_5 ha^{-1} + 100 kg K_20 ha^{-1}; 300 kg N ha^{-1} + 200 kg P_2O_5 ha^{-1} + 200 kg K_20 ha^{-1}; 450 kg N ha^{-1} + 300 kg P_2O_5 ha^{-1} + 300 kg K_20 ha^{-1}), each treatment was determined to consist of 10 observation samples.

The initial research stage was done by loosening the land by hoeing and making small embankments in each treatment plot. The size of the treatment plots was 2.5 m x 2.5 m, and the distance between plots was 1 m. The next stage was the seeding process for each rice variety, separated using seeding blocks in 5 places (according to the number of varieties used), and sowing takes 21 days.

Liming and application of chicken manure were conducted at the beginning of land preparation with a dose of dolomite lime of 1.05 tons ha^{-1} and a dose of chicken manure of 20 tons ha^{-1} mixed evenly with topsoil. The land was incubated for 2 weeks before planting. Planting was carried out on rice seedlings that were 21 days old after sowing. Each variety was buried in a treatment plot of 5 seeds per planting hole with a spacing of 25 cm x 25 cm, and replanting dead seedlings was done a maximum of 7 days after planting (DAP).

The urea, SP-36, and KCl fertilization were performed at 7 DAP, 21 DAP, and 35 DAP plants. The fertilization process was sprinkled in each treatment plot. The fertilizer dosage was applied according to the treatment. Furthermore, plant care was carried out by cleaning weeds at 6 DAP, 20 DAP, and 34 DAP and controlling pests and diseases that attack by spraying pesticides. Rice harvesting occurred when the rice grains had met the harvest criteria, meaning that the grains had reached 90% maturity and had turned yellow on each rice panicle.

The growth and yield of rice plants in the research were performed by measuring plant height from the base of the stem to the tip of the longest leaf using a meter during the maximum vegetative phase, the maximum number of tillers was calculated for all tillers that appeared in each plant clump, the number of productive tillers was counted before harvest for seedlings that produced panicles in each clump, the weight of 1,000 grains was observed by weighing 1,000 grains of ground dry grain, and the grain weight per plot was measured by weighing the milled dry grain in each treatment plot.

The data obtained was analyzed with analysis of variance (ANOVA). Further tests were carried out on the factors with a significant effect, using a Tukey test with a confidence level of 95%.

RESULTS AND DISCUSSION

Plant height

Analysis of variance (ANOVA) showed that variety treatment was significant on maximum plant height at the vegetative stage. On the other hand, the interaction of varieties and NPK fertilizer dosages was not significant. The Tukey test showed that the Tropiko variety had significantly higher plant height by 2.86%, 2.64%, 2.41%, and 0.77% compared to Inpari 43, Bima Saputra, Padang, and Argo Pawan varieties. In addition, the plant height of the Argo Pawan variety was significantly higher than the Bima Saputra, Inpari 43, and Padang varieties (Table 1). The genetic background of different plants can determine the rice plant's height (Kadir et al., 2016). The character of plant height is a standard hereditary characteristic possessed by each genotype (Putra et al., 2014). According to (Yulina et al., 2021), different plant genotypes show different plant height characteristics.

The better rice plant growth in this study, which is described by an increase in plant height, is caused by the suitability of the plant genotype to its growing environment. According to Rinawati and Rusmawan (2015), each variety has different responses to various environmental conditions where it grows, resulting in additional plant height growth. Furthermore, according to Hakim and Anandari (2019), the environment and climate of plants influence their development.

Table 1. The plant height with N, P, K fertilizer treatment and rice varieties.

N, P, K fertilizer (kg ha^{-1})	Plant height (cm)					Average
	Argo Pawan	Bima Saputra	Inpari 43	Padang	Tropiko	
150 N + 100 P_2O_5 + 100 K_20	96.97	88.07	87.07	89.93	100.43	92.49a
300 N + 200 P_2O_5 + 200 K_20	95.10	87.27	87.60	90.13	100.97	92.21a
450 N + 300 P_2O_5 + 300 K_20	99.57	90.30	87.87	88.70	100.87	93.46a
Average	97.21b	88.54c	87.51c	89.59 c	100.76a	

Note: Numbers followed by the same letter according to the column or row are not significantly different based on the Tukey test in the 5% level.

Maximum number of tillers

The analysis of variance (ANOVA) revealed that each treatment of varieties and NPK fertilizer dosages were significantly different in terms of the maximum number of tillers. However, the interaction of varieties and NPK fertilizer dosages was not significant. The Tukey test showed that Inpari 43 variety had significantly higher maximum number of tillers by 2.98%, 1.24%, 1.24%, and 1.12% compared to Padang, Argo Pawan, Tropiko, and Bima Saputra varieties. Furthermore, when using the Argo Pawan, Bima Saputra, and Tropiko varieties, the maximum number of tillers obtained similar results, which was significantly higher than the Padang variety (Table 2).

Internal factors greatly influence the formation of rice seedlings of a variety in the form of the genetic characteristics of the plant itself, while the external factors influence in the form of plant-growing environmental conditions such as climate conditions, soil,

and biotic factors (Sitinjak & Idwar, 2015; Anhar et al., 2016). According to Rembang et al. (2018), the number of tillers is a characteristic of a variety, so each variety has a different possibility of producing tillers.

The Tukey test result for the maximum number of tillers in the 450 kg N ha^{-1} + 300 kg P_2O_5 ha^{-1} + 300 kg K_20 ha^{-1} treatment was significantly higher by 1.86% than the 150 kg N ha^{-1} + 100 kg P_2O_5 ha^{-1} + 100 kg K_20 ha^{-1} treatment, but not significantly different than the treatment of 300 kg N ha^{-1} + 200 kg P_2O_5 ha^{-1} + 200 kg K_20 ha^{-1} (Table 2). This is due to the higher availability of N elements to plants, which aid cell division and elongation and promote seedling formation (Zhang et al., 2020; Suwarto et al., 2021). A balanced combination of N, P, and K fertilizers for plants increases the number of tillers in the growth process (Habibullah et al., 2015).

Table 2. The maximum number of tillers with N, P, K fertilizer treatment and rice varieties.

N, P, K fertilizer (kg ha^{-1})	Number of tiller per hill					Average
	Argo Pawan	Bima Saputra	Inpari 43	Padang	Tropiko	
150 N + 100 P_2O_5 + 100 K_20	17.33	17.33	18.67	16.00	17.33	17.33b
300 N + 200 P_2O_5 + 200 K_20	18.33	18.33	19.67	16.67	18.00	18.13a
450 N + 300 P_2O_5 + 300 K_20	18.67	18.67	19.00	16.67	18.67	18.33a
Average	18.00b	18.11b	19.11a	16.44c	18.00b	

Note: Numbers followed by the same letter according to the column or row are not significantly different based on the Tukey test in the 5% level.

Number of productive tillers

The analysis of variance (ANOVA) found that each treatment of rice varieties and NPK fertilizers dosages were significantly different in the number of productive tillers. Nevertheless, the interaction between varieties and NPK fertilizer dosages showed no significant results. The result of the Tukey test showed that the number of productive tillers in the Inpari 43 variety was significantly higher by 4.16%, 2.35%, and 1.25% compared to the use of the Padang, Bima Saputra, and Argo Pawan varieties, but not significantly different from the Tropiko variety (Table 3). According to Aryawati et al. (2022), several cultivated rice varieties have different effects on producing productive tillers. According to Suryanugraha et al. (2017), the ability of a variety to adapt to its growing environment results in optimal production achievements, including the ability to produce panicles.

The Tukey test showed that the number of productive tillers in the treatment of 300 kg N ha^{-1} + 200 kg P_2O_5 ha^{-1} + 200 kg K_20 ha^{-1} was more than 2.23% compared to treatment 150 kg N ha^{-1} + 100 kg P_2O_5 ha^{-1} + 100 kg K_20 ha^{-1}, but not significantly different from treatment 450 kg N ha^{-1} + 300 kg P_2O_5 ha^{-1} + 300 kg K_20 ha^{-1} (Table 3). This results from the role of phosphorus in rice plants, which stimulates the growth of the number of productive tillers (Syukri & Fajri, 2017). The increase in tillers formed aligned with increasing N, P, and K fertilizer doses. According to Badawi et al. (2017), Riyani and Purnamawati (2019), and Mboyerwa et al. (2021), applying more doses of N, P_2O_5, and K_2O to rice plants can promote the formation of panicles.

Table 3. The number of productive tillers with N, P, K fertilizer treatment and rice varieties.

N, P, K fertilizer (kg ha^{-1})	Number of productive tiller per hill					Average
	Argo Pawan	Bima Saputra	Inpari 43	Padang	Tropiko	
150 N + 100 P_2O_5 + 100 K_20	16.00	14.33	17.33	13.00	16.00	15.33b
300 N + 200 P_2O_5 + 200 K_20	16.67	16.00	17.67	15.33	16.33	16.40a
450 N + 300 P_2O_5 + 300 K_20	16.67	16.33	17.33	14.00	17.33	16.33a
Average	16.44b	15.56c	17.44a	14.11d	16.56ab	

Note: Numbers followed by the same letter according to the column or row are not significantly different based on the Tukey test in the 5% level.

Grain weight of 1,000 seeds

Following the analysis of variance, the weight of 1,000 grains showed a significant difference in the rice varieties. However, the interaction between the varieties and NPK fertilizer dosage showed no significant results. When comparing the weight of 1,000 grains using Tropiko varieties to Inpari 43 and Bima Saputra varieties, the Tukey test result showed that Tropiko was significantly heavier by 1.71% and 0.90%, respectively. There was no significant difference when comparing the Tropiko variety to the Argo Pawan and Padang varieties (Table 4). The difference in the weight of 1,000 grains shows the ability of a variety to display better characteristics in seed filling and adapt better to its growing environment, which improves the plant's metabolic processes. According to Zangani et al. (2021), the factors that influence the weight of 1,000 seeds are the plant's genetic factors and the suitability of the plant's growing environment.

Table 4. The grain weight of 1,000 seeds with N, P, K fertilizer treatment and rice varieties.

N, P, K fertilizer (kg ha^{-1})	Weight of 1,000 grains (g)					Average
	Argo Pawan	Bima Saputra	Inpari 43	Padang	Tropiko	
150 N + 100 P_2O_5 + 100 K_20	25.67	24.87	23.98	25.71	26.10	25.26a
300 N + 200 P_2O_5 + 200 K_20	26.08	26.05	23.95	25.89	26.30	25.45a
450 N + 300 P_2O_5 + 300 K_20	26.29	24.97	23.87	25.45	25.89	25.29a
Average	26.01a	24.96b	23.93c	25.68a	26.10a	

Note: Numbers followed by the same letter according to the column or row are not significantly different based on the Tukey test in the 5% level.

Grain weight per plot

Each treatment of rice varieties and NPK fertilizer dosages significantly differed the grain weight per plot, according to ANOVA. On the other hand, the interaction of varieties and NPK fertilizer dosages showed no significant results. The Tukey test results on the grain weight per plot revealed that the Inpari 43 variety was significantly heavier by 9.64%, 1.94%, and 1.63% compared to the Padang, Argo Pawan, and Bima Saputra varieties. However, there was no significant difference compared to the Tropiko variety (Table 5). This suggests that employing superior varieties with high production characteristics and adaptability to the growing environment supports increasing rice yields (Kosmiatin & Husni, 2018).

The Tukey test result on the grain weight per plot in the 300 kg N ha^{-1} + 200 kg P_2O_5 ha^{-1} + 200 kg K_20 ha^{-1} treatment was significantly heavier by 1.04% than the 150 kg N ha^{-1} + 100 kg P_2O_5 ha^{-1} + 100 kg K_20 ha^{-1} treatment, but it was not significantly different from the 450 kg N ha^{-1} + 300 kg P_2O_5 ha^{-1} + 300 kg K_20 ha^{-1} treatment (Table 5). This is because the higher the dosage of N, P, and K fertilizer applied, the better the availability of raw materials plants need for photosynthesis, so the assimilates available during seed development will influence seed weight (Widiana et al., 2017).

Table 5. The grain weight per plot with N, P, K fertilizer treatment and rice varieties.

N, P, K fertilizer (kg ha^{-1})	Grain weight per plot (kg)					Average
	Argo Pawan	Bima Saputra	Inpari 43	Padang	Tropiko	
150 N + 100 P_2O_5 + 100 K_20	2.67	2.65	2.85	1.62	2.86	2.53b
300 N + 200 P_2O_5 + 200 K_20	2.65	2.75	3.05	1.70	2.91	2.61a
450 N + 300 P_2O_5 + 300 K_20	2.69	2.74	2.87	1.73	2.87	2.58a
Average	2.67b	2.71b	2.92a	1.68c	2.88a	

Note: Numbers followed by the same letter according to the column or row are not significantly different based on the Tukey test in the 5% level

CONCLUSIONS

The Tropiko variety had the highest plant height compared to other varieties. The Inpari 43 variety produced most of the maximum number of tillers. Furthermore, the Inpari 43 and Tropiko varieties were the best treatments for producing the number of productive tillers and grain weight per plot. The N, P, and K fertilizer dosage of 300 kg N ha^{-1} + 200 kg P_2O_5 ha^{-1} + 200 kg K_20 ha^{-1} was the best treatment in producing growth and yields of rice plants based on the variables of maximum number of tillers, number of productive tillers, and grain weight per plot.

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