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The Effects of NPK Fertilization and Jajar Legowo Planting System in Acid Sulfate Rice Fields on the Growth and Yield of Inpari IR Nutri Zinc Rice

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Abstract:
Background*: Rice (Oryza sativa L) is a staple food for the majority of the world's population, and its availability must be ensured by the state. The Banjar Regency possesses a potential area of swampy land, which is generally characterized by acidic sulfate soil with a pH range of 2-3. Consequently, this condition leads to low productivity for rice crops cultivated on such land. Therefore, efforts to increase agricultural production need to be carried out through intensification, by implementing inorganic fertilization using NPK compound fertilizer and adjusting the planting distance with the jajar legowo planting system. This research has the purpose to find out the effect of the interaction between NPK fertilizer application and the jajar legowo planting system and to determine the individual effects of NPK fertilizer and the jajar legowo planting system on the growth and yield of Inpari IR Nutri Zinc rice cultivar.*
Materials and Methods*: The experimental design used was a Completely Randomized Design (CRD) with a two-factor factorial. The first factor was the dosage of NPK Phonska fertilizer (P), consisting of five treatment levels, namely:* p_0 *= 0 kg* ha^{-1} *,*p_1 *= 100 kg* ha^{-1} *,* p_2 *= 200 kg* ha^{-1} *,* p_3 *= 300 kg* ha^{-1} *,* p_4 *= 400 kg* ha^{-1} *, The second factor was the planting system (S), consisting of five treatment levels, namely:* s_1 *= The planting system using 25 cm x 25 cm spacing,* s_2 *= The planting system is the jajar legowo system 2 : 1,* s_3 *= The planting system is the jajar legowo system 3 : 1,* s_4 *= The planting system is the jajar legowo system 4 : 1,* s_5 *= The planting system is the jajar legowo system 5 : 1, Each experimental unit was replicated three times, resulting in a total of 75 experimental units.*
Results*: The interaction between NPK fertilizer application and the jajar legowo planting system significantly influences the weight of 1000 filled grains and yields higher results, with an average weight of 29.98 grams. The application of NPK Phonska fertilizer at a rate of 300 kg.ha-1 resulted in the best performance in terms of plant height, number of tillers, number of productive tillers per hill and number of grains per panicle compared to the application of NPK fertilizer at rates of 400 kg.*ha^{-1}*, 200 kg.*ha^{-1}*, 100 kg.*ha^{-1}*, and 0 kg.*ha^{-1}*.*
Conclusion: *The cultivation of Inpari IR Nutri Zinc rice on acid sulfate paddy fields can utilize NPK fertilizer at a rate of 300 kg.*ha^{-1} *and applying 25 cm x 25 cm tile planting system.*
Key Word*: Low fertility; pyrite; fertilizer; plant population.*

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I. Introduction

Rice (Oryza sativa L) is a primary food crop commodity and serves as a staple food for over half of the world's population. The Indonesian Law No. 18 of 2012 concerning Food states that food is the most fundamental human need, and its fulfillment is part of the human rights guaranteed by the state. The fulfillment of food needs within a country or a region in the Republic of Indonesia is an absolute necessity. Additionally, food plays a crucial and strategic role due to its close relationship with social, economic, and political factors. Based on the Food Law, Indonesia must have a robust food security system. Food security is not solely about achieving self-sufficiency in food supply but also involves household food security to reduce food vulnerability (Hanani, 2012). The main issue in food security lies in the faster growth of demand compared to supply (H.P. Saliem, 2003). Therefore, pregnant women are expected to consume rice that contains the necessary nutritional content. To address the issue of stunting, a high-Zinc rice variety called Inpari IR Nutri Zinc has been released. Its legal document is Minister of Agriculture Decree Number 68/HK.540/ZIN/01/2019. This variety has an average yield similar to Ciherang variety but with a higher Zinc content of 29.54 ppm.

The government's efforts to meet the food needs of its population are faced with significant and highly complex challenges. Programs and policies related to food security become the primary focus in agricultural development. Despite Indonesia being an agrarian country with abundant paddy fields, it still imports rice. The cause is the lack of domestic production. Rice is also a prominent staple commodity in Kabupaten Banjar. Within the scope of South Kalimantan Province, Kabupaten Banjar is one of the main rice production centers that significantly contributes to the total rice production in South Kalimantan. The Central Statistics Agency (BPS) in 2020 recorded that the rice productivity in Kabupaten Banjar was 3,513 t. ha^{-1}, which is lower than the rice productivity in South Kalimantan Province, which was 3,969 t. ha^{-1}, and significantly below the national rice productivity of 5,128 t. ha^{-1}. The quantity of rice production is not only determined by the planting system but also influenced by fertilization. The application of compound fertilizers can provide macro-nutrients with compositions/formulas tailored to the plant's needs, along with micro-nutrients (Scherer, 2007). Based on this background, there is a need for research on the effects of NPK fertilizer application with the row planting system on the growth and yield of Inpari IR Nutri Zinc rice. Considering the importance of Inpari IR Nutri Zinc rice for increasing rice production and providing a nutritious energy source for the community, this rice variety has great potential for development. The high zinc content is expected to meet the nutritional needs during the growth phase of children.

II. Material And Methods

This research is a field experiment conducted on acid sulfate paddy fields to investigate the optimal dosage of NPK fertilizer and the row planting system (jajar legowo) to achieve optimal results.

Research Design: The experimental design used in this research was a completely randomized factorial design with two factors. The first factor was the dosage of Phonska NPK fertilizer (P), consisting of five treatment levels: p_0 = 0 kg ha^{-1}, p_1 = 100 kg ha^{-1}, p_2 = 200 kg ha^{-1}, p_3 = 300 kg ha^{-1}, and p_4 = 400 kg ha^{-1}. The second factor was the planting system (S), consisting of five treatment levels: s_1 = 25 cm x 25 cm square planting system, s_2 = 2:1 legowo planting system, s_3 = 3:1 legowo planting system, s_4 = 4:1 legowo planting system, and s_5 = 5:1 legowo planting system. Each experimental unit was replicated three times, resulting in a total of 75 experimental units.

Research Location: The research was conducted in Sungai Rangas Hambuku Village, West Martapura Subdistrict, Banjar Regency, South Kalimantan Province, Indonesia.

Research Duration: The research was conducted for 4 months, from June 2022 to September 2022.

Procedure methodology

Observations were conducted on the following parameters: Plant height, measured from the soil surface to the highest part of the plant after summarization (cm); Number of tillers per clump; Number of productive tillers per clump (stem); Number of grains per panicle (grains); Weight of 1,000 filled rice grains (gram); and weight of Dry Milled Grain per plot (kg).

Statistical analysis

Data analysis was conducted using the F-test (ANOVA) at the significance level of $\alpha = 0.05$. If the treatment in the analysis of variance shows a significant effect, to determine which treatments are the same or different, a post hoc test of multiple comparisons is performed using Duncan's Multiple Range Test (DMRT) at the significance level of $\alpha = 0.05$.

III. Result and Discussion

The results of analysis of variance on the observation parameters of plant height at 3 MST ($x_{1.1}$), 4 MST ($x_{1.2}$), 5 MST ($x_{1.3}$), and 6 MST ($x_{1.4}$), the number of tillers per clump at 3 MST ($x_{2.1}$), 4 MST ($x_{2.2}$), 5 MST ($x_{2.3}$), and 6 MST ($x_{2.4}$), the number of productive tillers per clump (x_3), the number of grains per panicle (x_4), and the weight of 1,000 filled rice grains (x_6) are presented in Table 1 and Table 2.

Table 1. The results of analysis of variance on the observation parameters of plant height at 3 MST (x1.1), 4 MST (x1.2), 5 MST (x1.3), and 6 MST (x1.4), and the number of tillers per clump at 3 MST (x2.1), 4 MST (x2.2), 5 MST (x2.3), and 6 MST (x2.4).

SK	DB	Mean Square							
		$X_{1.1}$	$X_{1.2}$	$X_{1.3}$	$X_{1.4}$	$X_{2.1}$	$X_{2.2}$	$X_{2.3}$	$X_{2.4}$
P	4	$159,16^{**}$	$244,73^{**}$	$214,15^{**}$	$221,58^{**}$	$34,65^{**}$	$46,00^{**}$	$46,97^{**}$	$76,21^{**}$
S	4	$2,18^{ns}$	$7,38^{ns}$	$3,13^{ns}$	$21,50^{ns}$	$1,02^{ns}$	$17,71^{ns}$	$20,42^{*}$	$21,15^{*}$
P*S	16	$11,07^{ns}$	$11,15^{ns}$	$18,17^{ns}$	$11,98^{ns}$	$3,18^{ns}$	$4,14^{ns}$	$4,60^{ns}$	$4,98^{ns}$
Error	50	16,96	17,05	16,32	12,92	2,81	7,73	6,61	5,56
KK (%)		8,46	7,33	6,52	5,15	24,74	24,42	19,94	17,56

Table 2. The results of analysis of variance on the observation parameters of the number of productive tillers per clump (x_3), the number of grains per panicle (x_4), and the weight of 1,000 filled rice grains (x_5).

SK	DB	Kuadrat Tengah		
		X_3	X_4	X_5
P	4	15,76**	496,52**	151,95**
S	4	14,33**	319,28**	16,95**
P*S	16	1,97ns	91,50ns	11,08**
Galat	50	2,85	77,96	1,42
KK		17,11	8,21	5,35

Plant Height

Plant height is measured from the soil surface to the highest point of the plant after being summarized (cm). According to Iswahyudi et al. (2017) in (Sri Widata & Pamungkas, 2019), the application of a high amount of NPK fertilizer can increase plant height growth, especially nitrogen fertilizer, which accelerates vegetative plant growth.

Based on the analysis of variance, the interaction between NPK fertilizer application and planting system, as well as the individual effects of the planting system, do not have a significant impact on plant height during the observation at 3 MST, 4 MST, 5 MST, and 6 MST. However, the individual effect of NPK fertilizer application has a highly significant impact on plant height during the observation at 3 MST, 4 MST, 5 MST, and 6 MST. The influence of NPK fertilizer on plant height is presented in Table 3.

Table 3. The Effect of NPK Fertilizer on Plant Height at 3 MST, 4 MST, 5 MST, and 6 MST (weeks after sowing)

Treatment of NPK Fertilizer	Plant Height (cm)			
	3 MST	**4 MST**	**5 MST**	**6 MST**
0 kg.ha^{-1}	44,44 ^{a}	51,00 ^{a}	57,41 ^{a}	65,42 ^{a}
100 kg.ha^{-1}	47,76 ^{b}	54,44 ^{b}	60,10 ^{ab}	67,54 ^{ab}
200 kg.ha^{-}	48,00 ^{b}	57,10 ^{bc}	60,95 ^{b}	68,81 ^{b}
300 kg.ha^{-1}	53,17 ^{c}	61,22 ^{d}	66,94 ^{c}	72,98 ^{c}
400 kg.ha^{-1}	49,97 ^{b}	58,41 ^{cd}	64,29 ^{c}	74,58 ^{c}

Explanation: Mean values with the same superscript letter in the same column are not significantly different based on Duncan's Multiple Range Test (DMRT) at the 5% level of significance.

In Table 3, it can be observed that during the 3rd week after sowing (MST), the application of 300 kg.ha^{-1} NPK fertilizer results in higher plant growth compared to the application of 400 kg.ha^{-1}, 200 kg.ha^{-1}, 100 kg.ha^{-1}, and the treatment without NPK fertilizer (0 kg.ha^{-1}). However, during the 4th, 5th, and 6th weeks after sowing (MST), the application of 300 kg.ha-1 NPK fertilizer does not differ significantly from the application of 400 kg.ha^{-1} NPK fertilizer, and both result in higher plant height compared to the application of 200 kg.ha^{-1}, 100 kg.ha^{-1}, and the treatment without NPK fertilizer (0 kg.ha^{-1}).

Number of Tillers

Based on the analysis of variance, the interaction between NPK fertilizer application and planting system does not have a significant effect on the number of tillers during the observation at 3 MST, 4 MST, 5 MST, and 6 MST. However, the individual effect of NPK fertilizer application has a highly significant impact on the number of tillers during the observation at 3 MST, 4 MST, 5 MST, and 6 MST, and the individual effect of the planting system has a significant impact on the number of tillers during the observation at 5 MST and 6 MST. The influence of NPK fertilizer on the number of tillers is presented in Table 4.

Table 4. The Effect of NPK Fertilizer on the Number of Tillers at 3 MST, 4 MST, 5 MST, and 6 MST (weeks after sowing)

Treatment		Number of tillers			
		3 MST	**4 MST**	**5 MST**	**6 MST**
0 kg.ha^{-1}		5,03^{a}	9,64^{a}	11,23^{a}	11,07^{a}
100 kg.ha^{-1}		6,09^{ab}	10,68^{a}	12,34^{ab}	12,85^{a}
200 kg.ha^{-1}		6,42^{b}	10,02^{a}	11,25^{a}	11,57^{a}
300 kg.ha^{-1}		9,01^{d}	13,61^{b}	15,33^{c}	16,54^{b}
400 kg.ha^{-1}		7,40^{c}	12,89^{b}	14,19^{bc}	14,97^{b}

Explanation: Mean values followed by the same superscript letter in the same column are not significantly different based on Duncan's Multiple Range Test (DMRT) at the 5% level of significance.

In Table 4, it can be observed that during the 3rd week after sowing (MST), the application of 300 kg.ha^{-1} NPK fertilizer results in a greater number of tillers compared to the application of 400 kg.ha-1, 200 kg.ha-1, 100 kg.ha-1, and the treatment without NPK fertilizer. However, during the 4th, 5th, and 6th weeks after sowing (MST), the application of 300 kg.ha^{-1} NPK fertilizer does not differ significantly from the application of 400 kg.ha^{-1} NPK fertilizer, and both result in a greater number of tillers compared to the application of 200 kg.ha^{-1}, 100 kg.ha^{-1}, and the treatment without NPK fertilizer.

This is suspected to be because the application of 300 kg.ha^{-1} of Phonska NPK fertilizer is capable of providing optimal nutrients for rice growth, thus enhancing the photosynthesis process. This is consistent with the findings of Paiman (2019) which stated that NPK fertilizer application can increase the number of tillers in rice plants compared to the control. The presence of phosphorus (P) in compound NPK fertilizers plays a crucial role during the formation of rice tillers.

The effect of planting distance on the number of tillers is presented in Table 5.

Table 5. The Effect of Planting Distance on the Number of Tillers at 5 MST and 6 MST (weeks after sowing).

Treatment of planting system	Number of tillers	
	5 MST	6 MST
25 cm x 25 cm square	14,82^{b}	15,32^{b}
legowo 2 :1	11,65^{a}	12,03^{a}
legowo 3 :1	12,59^{a}	13,33^{a}
legowo 4 :1	12,65^{a}	13,11^{a}
legowo 5 :1	12,77^{a}	13,37^{a}

Explanation: Mean values followed by the same superscript letter in the same column are not significantly different based on Duncan's Multiple Range Test (DMRT) at the 5% level of significance.

In Table 5, it can be observed that during the 5th and 6th weeks after sowing (MST), the 25 cm x 25 cm square planting system differs significantly and results in a greater number of tillers compared to the 2:1 legowo planting system, the 3:1 legowo planting system, the 4:1 legowo planting system, and the 5:1 legowo planting system.

Number of Productive Tillers per Clump

Based on the analysis of variance, the interaction between NPK fertilizer application and planting system does not have a significant effect on the number of productive tillers per clump during the observation at 1 week before harvest (MSP). However, the individual effects of NPK fertilizer application and planting system have a highly significant impact on the number of productive tillers per clump during the observation at 1 MSP. The influence of NPK fertilizer and planting system on the number of productive tillers per clump is presented in Table 6.

Table 6. The Effect of NPK Fertilizer and Planting System on the Number of Productive Tillers per Clump at 1 MSP (Month after Sowing).

Treatment	Number of productive tillers per clump
	1 MSP
Treatment	
0 kg.ha^{-1}	9,45^{a}
100 kg.ha^{-1}	9,15^{a}
200 kg.ha^{-1}	8,75^{a}
300 kg.ha^{-1}	11,07^{b}
400 kg.ha^{-1}	10,83^{b}
Planting System	
25 cm x 25 cm square	11,31^{c}
legowo 2 :1	8,57^{a}
legowo 3 :1	9,93^{b}
legowo 4 :1	9,60^{ab}
legowo 5 :1	9,89^{b}

Explanation: Mean values followed by the same superscript letter are not significantly different based on Duncan's Multiple Range Test (DMRT) at the 5% level of significance.

In Table 6, it can be observed that the application of 300 kg.ha^{-1} NPK fertilizer during the first observation period (MSP) is not significantly different from the application of 400 kg.ha^{-1} NPK fertilizer, and it results in a greater number of productive tillers per clump compared to the application of 100 $kg.ha^{-1}$ and 200 $kg.ha^{-1}$ NPK fertilizers, as well as the treatment without NPK fertilizer.

Moreover, in Table 6, it is evident that the planting system treatment during the first observation period (MSP) shows that the 25 cm x 25 cm square planting system produces a greater number of productive tillers per clump compared to the 2:1 legowo planting system, the 3:1 legowo planting system, the 4:1 legowo planting system, and the 5:1 legowo planting system.

Number of grains per panicle

The analysis of variance results indicates that the interaction between NPK fertilizer application and planting system does not have a significant effect on the number of grains per panicle. However, the individual effects of NPK fertilizer application and planting system have a highly significant impact on the number of grains per panicle. The average effects of NPK fertilizer and planting distance on the number of grains per panicle are presented in Table 7.

Table 7. The Effect of NPK Fertilizer and Planting System on the Number of Grains per Panicle.

Treatment	**Number of grains per panicle**
NPK Fertilizer	
0 $kg.ha^{-1}$	$98,29^{a}$
100 $kg.ha^{-1}$	$107,08^{b}$
200 $kg.ha^{-1}$	$110,11^{b}$
300 $kg.ha^{-1}$	$113,07^{b}$
400 $kg.ha^{-1}$	$109,29^{b}$
Planting System	
25 cm x 25 cm square	$106,53^{a}$
legowo 2 :1	$105,07^{a}$
legowo 3 :1	$107,35^{a}$
legowo 4 :1	$103,24^{a}$
legowo 5 :1	$115,25^{b}$

Mean values followed by the same superscript letter are not significantly different based on Duncan's Multiple Range Test (DMRT) at the 5% level of significance.

In Table 7, it can be observed that the application of 300 $kg.ha^{-1}$ NPK fertilizer does not differ significantly from the application of 100 $kg.ha^{-1}$, 200 $kg.ha^{-1}$, and 400 $kg.ha^{-1}$ NPK fertilizers, but it provides the best result with the highest average number of grains per panicle, 113.07, compared to the treatment without NPK fertilizer at 0 $kg.ha^{-1.}$

In Table 7, it can be observed that the 5:1 legowo planting system differs significantly from the 4:1 legowo planting system, the 3:1 legowo planting system, the 2:1 legowo planting system, and the 25 cm x 25 cm square planting system. The 5:1 legowo planting system yielded the highest result with an average number of grains per panicle of 115.25 compared to other legowo planting systems.

Weight of 1,000 filled rice grains

Based on the analysis of variance, it is evident that the interaction between NPK fertilizer application and planting system, as well as the individual effects of NPK fertilizer application and planting system, significantly influence the weight of 1,000 filled rice grains. The impact of NPK fertilizer and planting system on the weight of 1,000 filled rice grains is presented in Table 8.

Table 8. The Effect of NPK Fertilizer and Planting System on the Weight of 1,000 Filled Rice Grains

Treatment	**Weight of 1,000 filled rice grains**
NPK Fertilizer	
0 $kg.ha^{-1}$	$20,14^{b}$
100 $kg.ha^{-1}$	$18,98^{a}$
200 $kg.ha^{-1}$	$21,72^{c}$
300 $kg.ha^{-1}$	$26,01^{e}$
400 $kg.ha^{-1}$	$24,84^{d}$
Planting System	
25 cm x 25 cm	$22,46^{b}$
legowo 2 :1	$22,66^{b}$
legowo 3 :1	$21,01^{a}$
legowo 4 :1	$21,48^{a}$
legowo 5 :1	$23,72^{c}$

The mean values followed by the same superscript letter are not significantly different based on Duncan's Multiple Range Test (DMRT) at the 5% level of significance.

From Table 8, it can be observed that the application of 300 kg.ha-1 NPK fertilizer resulted in a higher weight of 1,000 filled rice grains compared to the application of NPK fertilizer at 0 kg.ha-1, 100 kg.ha-1, 200 kg.ha-1, and 400 kg.ha-1 rates. Table 6 also indicates that the 5:1 legowo system planting produces the highest weight of 1,000 filled rice grains compared to the 25 cm x 25 cm square planting system, 2:1 legowo system planting, 3:1 legowo system planting, and 4:1 legowo system planting.

Table 9. The Effect of NPK Fertilizer and Planting Distance Interaction on the Weight of 1,000 Grains of Filled Rice

NPK Fertilizer ($kg\ ha^{-1}$)	Weight of 1,000 filled rice grains (grams).				
	s_1	s_2	s_3	s_4	s_5
0 $kg.ha^{-1}$	$19{,}83^{bcd}$	$20{,}23^{bcde}$	$20{,}4^{cde}$	$18{,}63^{bc}$	$21{,}6^{defg}$
100 $kg.ha^{-1}$	21^{def}	18^{b}	15^{a}	$19{,}8^{bcd}$	18^{b}
200 $kg.ha^{-1}$	$23{,}43^{ghij}$	$21{,}63^{defg}$	$19{,}83^{bcd}$	21^{def}	24^{hijk}
300 $kg.ha^{-1}$	$24{,}63^{ijkl}$	$27{,}06^{m}$	$22{,}76^{fghi}$	$25{,}76^{klm}$	$29{,}83^{n}$
400 $kg.ha^{-1}$	$23{,}41^{ghij}$	$26{,}4^{lm}$	$27{,}03^{m}$	$22{,}18^{efgh}$	$25{,}16^{jklm}$

The mean values followed by the same superscript letter are not significantly different based on DMRT at the 5% level.

In Table 9, the results of the combination of treatments of NPK fertilizer application with different planting systems on the weight of 1,000 filled grains can be observed. The highest interaction effect is observed in the treatment where 300 $kg.ha^{-1}$ of NPK fertilizer is applied in combination with the 5:1 row planting system, resulting in an average weight of 29.83 grams. On the other hand, the lowest interaction effect is obtained from the treatment with 100 $kg.ha^{-1}$ of NPK fertilizer and the 3:1 row planting system, with an average weight of 15 grams.

IV. Conclusion

The research results indicate that the interaction between the application of 300 $kg.ha^{-1}$ of NPK Phonska fertilizer and the 5:1 row planting system significantly affects only the parameter of the weight of 1,000 filled grains. The interaction of the NPK Phonska 300 $kg.ha^{-1}$ treatment with the 5:1 row planting system resulted in 1,000 filled grains weighing 29.98 grams, which is significantly higher compared to the description of Inpari IR Nutri Zinc rice, which weighs 24.6 grams.

The single factor of applying 300 $kg.ha^{-1}$ of NPK Phonska fertilizer resulted in better outcomes in terms of plant height, number of tillers, number of productive tillers per clump and number of grains per panicle.

As a result, it can be recommended to cultivate Inpari IR Nutri Zinc rice on acid sulfate paddy fields using 300 $kg.ha^{-1}$ of NPK Phonska fertilizer and applying 25 cm x 25 cm tile planting system.

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