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The Growth and Yield of Upland Rice (*Oryza sativa* L.) Applied by Rice Husk Zeolite and Potassium Fertilizer

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ABSTRACT

The productivity of upland rice on sub-optimal land such as Ultisol is low. Increasing rice productivity can be attempted, for example, by applying rice husk zeolite and K fertilizer. This research aims to study the interaction of rice husk zeolite with K fertilizer on the growth and yield of upland rice on Ultisol. The research was conducted at the Soil and Greenhouse Laboratory, Faculty of Agriculture, University of Riau, from June to October 2022. The research was conducted experimentally in a factorial with a completely randomized design (CRD). The first factor was rice husk zeolite consisting of 3 levels (0, 200, and 400 kg ha^{-1}), and the second factor was K fertilizer consisting of 3 levels (0, 50, and 100 kg K_2O ha^{-1}), each interaction repeated three times. The results showed that the combination value of rice husk zeolite at a dose of 200 kg ha^{-1} with K fertilizer at a dose of 50 kg K_2O ha^{-1} increased the number of healthy grains per panicle by 21%, the proportion of healthy grain by 14% and the weight of dry milled grain by 32.25% compared to without rice husk zeolite and K fertilizer.

Keywords: Actual, citrus, land characteristics, land suitability, potential

INTRODUCTION

Approximately 90% of Indonesia's population consumes rice (*Oryza sativa* L.) as a staple food. The need for rice is increasing along with the increase in population yearly. Therefore, there is a need for a solution to increase rice production. One effort can be made to plant upland rice on dry land.

The potential and widely available dry land is the Ultisol type. Ultisol's land area in Indonesia is around 25% of the total land area of Indonesia, or 45 million ha (Prasetyo and Suriadikarta, 2006). Ultisol is classified as sub-optimal land with very low natural productivity. The low productivity is due to various constraints, including acid sensory soil, low organic matter content, cation exchange capacity (CEC), base saturation, and low availability of N, P, K, Ca, and Mg nutrients (Fitriatin et al., 2014). Various efforts have been made to increase the productivity of food crops on dry land, including upland rice, finding superior upland rice varieties, and seeking technological innovations and the correct dosage of fertilizers. According to researchers or breeders, the Inpago 12 variety, one of the superior upland rice varieties, produces 6.7 Mg ha^{-1} and a yield potential of 10.2 Mg ha^{-1} (BBPP, 2017).

One of the technological innovations to overcome the complex constraints on Ultisol soils is the application of synthetic zeolite, for example, rice husk zeolite, namely zeolite synthesized from rice husks. The advantage of zeolite is that it has a high CEC. Katsuki and Komarneni (2009) reported a CEC value of rice husk zeolite of 506 cmol kg^{-1}.

The high CEC of zeolite can increase the soil's ability to absorb water and nutrients. If the cations adsorbed on the zeolite adsorption site are anions with a valence of 2 or more, a second layer with a positive charge will appear so that they can adsorb anions or air. Hardjowigeno (2010) states that colloidal particles are generally negatively charged. Therefore, positively charged ions or cations are attracted to the colloid, forming an ionic double layer. Therefore, the ability of rice husk zeolite to absorb nutrients and water is tremendous because it has a very high CEC so that nutrients are not lost due to leaching and are available to plants during the growth phase. Johan et al. (2017) reported that the coal fly ash zeolite increased rice's growth and yield and reduced rice's heavy metal Cd levels by 0.4 mg kg^{-1}. Putri (2022) reported that giving coal fly ash zeolite at a dose of 100 kg ha^{-1} and catfish LOF at a dose of 400 mL per clump increased the weight of dry milled grain of upland rice by 68% compared to without zeolite and LOF. Nursanti's (2019) research results show that administration of POME-zeolite can reduce the content of exchangeable Al and exchangeable H acid cations by 71.21% and 27.71% respectively.

Associated with the low K in Ultisol, it requires the addition of K fertilizer. Potassium is a primary macronutrient which is required in large quantities. The central role of K in plants is as a cofactor for most enzymes; K also plays a role in the translocation and metabolism of carbohydrates (Wiraatmaja, 2016). Potassium plays a role in strengthening plant organs, accelerating the flowering and fruiting process, and increasing plant resistance to pests, diseases, and drought. This research aims to determine the effect of the interaction of rice husk zeolite and K fertilizer and the main effect of both to get the best treatment from the application of rice husk zeolite and K fertilizer on the growth and yield of upland rice plants on Ultisol soil.

MATERIALS AND METHODS

The research was conducted at the Soil and Greenhouse Science Laboratory, Faculty of Agriculture, University of Riau, from June to October 2022.

The materials used were upland rice seeds of the Inpago 12 variety, the topsoil of Ultisol taken in Balam Jaya Village, Tambang District, Kampar Regency, Riau, the rice husk zeolite used had a CEC value of 142.87 cmol kg^{-1}, Urea fertilizer, SP-36, KCl as a source of N, P, and K, Insecticide Imidacloprid 5%, fungicide Propineb 70%, $Al(OH)_3$ and NaOH as a chemical for synthetic rice husk zeolite.

The tools used are an oven, furnace, porcelain cup, SAA, hot plate, 25 mesh size soil sifter, flame photometer, pH meter, analytical balance, and spectrophotometer.

The study was conducted experimentally in factorial form using a completely randomized design (CRD). The first factor was rice husk zeolite, which consisted of 3 levels (0, 200, and 400 kg ha^{-1}). The second factor was K fertilization, which consisted of 3 levels (0, 50, and 100 kg K_2O ha^{-1}); each treatment was repeated three times.

The data obtained were analyzed statistically using analysis of variance (Analysis of Variance) based on the F test at the 5% level. The results of the F test showed that the treatment had a natural or non-real effect. Further tests were carried out using the Duncan New Multiple Range Test (DNMRT) at the 5% level.

Ultisols soil as a planting medium were dried for one week, then the soils were pounded and sifted using a sieve 25 mesh, mixed thoroughly, weighed 10 kg, and put into a polybag. Each polybag is arranged at a distance of 50 × 50 cm. Application of essential fertilizer sourced from Urea and SP-36 at doses of 125 and, respectively, 100 kg ha^{-1} (1.3587 and 1.388 g per polybag) and rice husk zeolite treatment according to dosage 0, 200, and 400 kg ha^{-1} are weighed and applied simultaneously by stirring evenly to the top 1/3 of the soil. Two 18-day-old seeds are planted in each polybag. One week after planting, thinning is carried out where

Table 1. Characteristics and Initial soil chemical properties and rice husk zeolite used for research

Parameters (Unit)	Unit	Value	Level*
pH	H_2O	4.72	Acid
pH	KCl	3.88	-
Organic carbon	%	1.59	Low
Total-N	%	0.34	Medium
C/N ratio	-	4.68	Very Low
Available P_2O_5 (Bray 1)	Ppm	31.92	Very high
Total P_2O_5 (HCl 25%)	mg.100g^{-1}	63.44	Very high
Base saturation	%	31.72	Low
CEC	cmol(+) kg^{-1}	10.15	Low
Al is exchangeable	cmol(+) kg^{-1}	2.96	-
H is exchangeable	cmol(+) kg^{-1}	4.48	-
Saturation Al	%	27.77	High
CEC rice husk zeolite	cmol(+) kg^{-1}	142.87	Very high

Note = * Based on the criteria of soil characteristics proposed by Soil Research Institute (2009) one seed that grows well and is healthy is maintained until harvest. Maintenance is carried out until harvest, including watering, weeding, and controlling pests and diseases. Embroidery is done twice a day according to the plant's needs. Weeding is carried out routinely once a week by manually pulling out every weed that grows in the polybag and planting area. Pest and disease control is carried out four times during the planting period by spraying insecticide (Regent 50 SC and Abamectin 18 g L^{-1}) and fungicide (Antracol 70 WP) in doses according to the recommended dosage for each product.

RESULTS AND DISCUSSIONS

Initial Soil Chemistry of Ultisols

Table 1 shows that the Ultisols soil used in the study reacted acidly with a pH of H_2O 4.72. The C/N and Ca exchangeable ratios are classified as very low. The content of C-organic and Mg is exchangeable, and BS and CEC of soil are low. The N-Total, K is exchangeable, and Na exchangeable soils were moderate, but the soil Al saturation was high, while the P-Bray 1, P_2O_5 (25% HCl), and K_2O (25% HCl) content was very high. Antoro and Nelvia (2018) reported that Ultisol Batu Belah, Kampar, and Riau have an acid reaction with low fertility, and Ca exchangeable values are very low. C-organic, CEC, and Mg exchangeable values are low, except for Al saturation, which is very high. Zulputra et al. (2014) reported that Ultisol Pematang Berangan, Rambah, Rokan Hulu, and Riau reacted sourly to a low fertility rate. The CEC of the rice husk zeolite used was very high, namely 142.87 cmol (+) kg^{-1}.

The Growth of Upland Rice

The Plant Height, Maximum Number of Tillers, and Productive Tillers

Table 2 shows that the interaction of rice husk zeolite with K fertilizer at each dose combination had no significant effect on plant height, maximum number of tillers, and rice panicles of upland rice plants compared to no treatment, as well as the main effect of rice husk zeolite or K fertilizer compared to no zeolite rice husk or without K fertilizer for each parameter.

Zeolite has a very high ability to absorb water and nutrients because it has a very high CEC value and multiple adsorption sites. The CEC value of the rice husk zeolite used was 142.87 cmol kg^{-1}. Applying synthetic zeolite and increasing the dose

Table 2. The Plant Height, Maximum Number of Tillers and Panicle.

Rice husk zeolite dose (kg ha^{-1})	K Fertilizer dose (kg K_2O ha^{-1}) 0	50	100	Average
		Plant Height		
		……cm……		
0	115.20 a	120.63 a	116.17 a	117.33 a
200	112.20 a	122.67 a	122.47 a	119.11 a
400	117.47 a	120.03 a	116.43 a	117.97 a
Average	114.95 a	121.11 a	118.35 a	
		Maximum Number of Tillers		
		……tillers…..		
0	17.00 a	16.00 a	14.00 a	15.67 a
200	16.00 a	18.67 a	16.00 a	16.89 a
400	15.00 a	17.33 a	16.33 a	16.22 a
Average	16.00 a	17.33 a	15.44 a	
		Panicle		
		……tillers…..		
0	16.67 a	14.67 a	13.67 a	15.00 a
200	14.00 a	17.00 a	15.33 a	15.44 a
400	14.67 a	15.00 a	14.67 a	14.78 a
Average	15.11 a	15.56 a	14.56 a	

Note: Numbers in the same row and column followed by the same lowercase letters are not significantly different according to the DNMRT test at the 5% level.

plays a role in increasing the ability of the soil to absorb nutrients and water. However, it does not contribute to supplying nutrients because it does not contain nutrients, so its effect does not affect these parameters.

Every metabolic process in plants is an enzymatic process, namely a process that involves enzymes (catalysts). K acts as a cofactor for most of the enzymes in plants through metabolic processes. The primary function of K is as an enzyme cofactor (Uliyah et al., 2017), which plays a role in the translocation and metabolism of carbohydrates (Wiraatmaja, 2016). therefore, increasing the dose of K has no significant effect on this parameter.

Research by Hartati et al. (2019) shows the administration of 150 kg K_2O ha^{-1} produces the highest plant height, namely 92.66 cm, but it is not much different from 100 kg K_2O ha^{-1}, namely 91.92 cm. Rahman et al. (2019) reported that applying KCl fertilizer with various doses, including 200, 250, 300, and 350 kg K_2O ha^{-1}, showed different results but did not significantly increase the height of cabbage plants. The research results of Rahmi et al. 2023 shows the best growth and production of corn plants, namely in the HZ2 (Humate Zeolite 25 l ha^{-1}) treatment, namely from a height of 3.67 cm to 5.00 cm.

The Yield of Upland Rice

The Age of Out Panicles and Age of Harvest

Table 3 shows that the combination value of rice husk zeolite dose of 200 kg ha^{-1} with K fertilizer dose of 50 kg K_2O ha^{-1} accelerated panicle exit and harvest compared to no treatment or with other treatments except with combination value of rice husk zeolite dose of 400 kg ha^{-1} and K fertilizer dose of 50 kg K_2O ha^{-1} and rice husk zeolite dose of 200 kg ha^{-1} and K fertilizer dose of 100 kg K_2O ha^{-1} (for panicle budding age only).

Table 3 shows that the primary treatment of rice husk zeolite at a dose of 200 kg.ha^{-1} accelerated panicle exit and harvest compared to without rice husk zeolite except by giving rice husk zeolite at a dose of 400 kg ha^{-1}. The primary treatment with a K fertilizer dose of 50 kg K_2O ha^{-1} accelerated panicle exit and harvest compared to no K fertilizer or 100 kg K_2O ha^{-1}. It is closely related to the function of zeolites, which absorb nutrients in the soil so that nutrients are available to plants and utilized during panicle formation and fruit ripening. Potassium, in this case, acts as an enzyme cofactor, thus spurring metabolic processes that support panicle formation and grain filling (forming panicle, flower, and grain tissue). Potassium acts as an enzyme cofactor in the metabolism of flowering, fertilization, and panicle growth, thereby accelerating grain ripening.

Table 3 shows that the application of K fertilizer at a dose of 100 kg K_2O ha^{-1} slowed the age of panicle exit and harvest when compared to the application of K fertilizer at a dose of 50 kg K_2O ha^{-1}; this resulted in competition between one-valent cations, namely K^+ and NH^{4+} in occupying root adsorption sites, when K is added to plants in large quantities, results in disruption of N uptake, whereas

Table 3. The Age of Out Panicles and Age of Harvest of upland rice plants treated with rice husk zeolite and K fertilizer

Rice husk zeolite dose (kg.ha^{-1})	K Fertilizer dose (kg K_2O.ha^{-1})			Average
	0	50	100	
Age of Out Panicles				
…… days after planting ……				
0	70.00 ab	69.33 ab	71.67 a	70.33 a
200	69.33 ab	65.33 c	68.00 abc	67.55 b
400	70.00 ab	67.00 bc	69.67 ab	68.89 ab
Average	69.77 a	67.22 b	69.78 a	
Age of Harvest				
…… days after planting ……				
0	95.33 a	93.33 ab	96.67 a	95.11 a
200	94.67 ab	88.33 c	93.00 ab	92.00 b
400	95.33 a	90.67 bc	94.67 ab	93.56 ab
Average	95.11 a	90.77 b	94.78 a	

Note: Numbers in the same row and column followed by the same lowercase letters are not significantly different according to the DNMRT test at the 5% level.

Table 4. The maximum number of tillers and productive tillers of upland rice plants aged 56 HST treated with rice husk zeolite and K fertilizer.

Rice husk zeolite dose (kg ha^{-1})	K Fertilizer dose (Kg K_2O ha^{-1})			Average
	0	50	100	
Maximum number of tiller				
……tillers…..				
0	70.00 ab	69.33 ab	71.67 a	70.33 a
200	69.33 ab	65.33 c	68.00 abc	67.55 b
400	70.00 ab	67.00 bc	69.67 ab	68.89 ab
Average	69.77 a	67.22 b	69.78 a	
Productive number of tiller				
……tillers…..				
0	95.33 a	93.33 ab	96.67 a	95.11 a
200	94.67 ab	88.33 c	93.00 ab	92.00 b
400	95.33 a	90.67 bc	94.67 ab	93.56 ab
Average	95.11 a	90.77 b	94.78 a	

Note: Numbers in the same row and column followed by the same lowercase letters are not significantly different according to the DNMRT test at the 5% level.

whatever K is absorbed by plants does not affect plant tissue formation if plant tissue-forming elements are not available.

Applying a zeolite dose of 200 kg ha^{-1} and a K fertilizer dose of 50 kg K_2O ha^{-1} is sufficient for the needs of plants so that the plants are utilized optimally. Available K in the soil given rice husk zeolite at a dose of 200 kg ha^{-1} was classified as high, namely 0.87 cmol kg^{-1}.

Number of Filled Grains per Panicle

Table 4 shows that the combination value of giving rice husk zeolite at a dose of 200 kg ha^{-1} with K fertilizer at a dose of 50 kg K_2O ha^{-1} increased the number of rice grains per panicle compared to without giving rice husk zeolite and without K fertilizer by 21%.

The role of zeolite is only to absorb nutrients, not as a nutrient contributor, as previously explained. Putri (2022) reported that synthetic zeolite at various doses showed no significant effect on the number of rice grains per panicle of upland rice plants compared to no zeolite. Zeolite can store the availability of nutrients so that they are fulfilled in the grain-filling process. The nutrient content is deep enough that the photosynthesis process produces more photosynthates, increasing rice grains (Habibullah, 2015). Giving the correct dose of fertilizer can increase plant growth due to the efficiency of fertilization, which is used optimally

Table 5. Number of filled grains per panicle in upland rice treated with rice husk zeolite and K fertilizer.

Rice husk zeolite dose (kg ha^{-1})	K Fertilizer dose (kg K_2O ha^{-1})			Average
	0	50	100	
……grain…..				
0	147.34 ab	141.62 ab	132.92 b	140.63 a
200	145.57 ab	179.27 a	149.40 ab	158.08 a
400	160.60 ab	152.59 ab	137.77 b	150.32 a
Average	151.17 a	157.82 a	140.03 a	

Note: Numbers in the same row and column followed by the same lowercase letters are not significantly different according to the DNMRT test at the 5% level according to plant needs. According to Hartati et al. (2018), K can increase the allocation of assimilates from the leaves to the grain, thereby increasing the weight of the filled grain in the plant. According to Wachid and Mintono (2017), the formation of the number of rice grains depends on the results of the photosynthesis process that occurs during the grain-filling phase during the growth period. Annisa et al. (2014) shows that the effect of using zeolite 200 gm-2 -2 on tuber production using mulch shows a higher value, namely 81.50% (1,299.94 g) when compared to without mulch.

The Percentage of Filled Grains

Table 5 shows that the combination value of rice husk zeolite doses of 0, 200, and 400 kg ha^{-1} with K fertilizer doses of 0, 50, and 100 kg K_2O ha^{-1} was not significant as were the main factors of rice husk zeolite and fertilizer. Potassium to the proportion of rich grain, but in the combination value of giving rice husk zeolite dose of 200 kg ha^{-1} and K fertilizer dose of 50 kg K_2O ha^{-1} increased the proportion of rice husk of upland rice plants by 14% when compared without giving rice husk zeolite with fertilizer K.

The increasing is closely related to the role of zeolite in absorbing water and nutrients to ensure the availability of air and nutrients to the generative phase, which can improve physiological and metabolic processes. Rosalina and Nirwanto (2021) reported that translocation and accumulation of photosynthate products in the stems and leaves greatly determine the level of grain filling, in which the more photosynthate results, the more grain will be filled.

In this case, potassium plays a role in carbohydrate translocation and carbohydrate metabolism, such as the formation of starch, protein, fat, and others as a grain component, but does not directly affect the amount of carbohydrates (photosynthate) produced. Potassium is an element needed by plants in the formation of starch and the translocation of photosynthetic products such as sugar (Pranico, 2022).

Chen et al. (2017) reported that applying zeolite could significantly reduce the percentage of empty grain in the second planting period. Putri's research (2022) reported giving zeolite fly ash at a dose of 100 kg.ha^{-1} showed an increase in the percentage of rice grain by 11.89%.

The Weight of 1000 Filled Grains

Table 6 shows that the combination value of giving rice husk zeolite doses of 0, 200 and 400 kg ha^{-1} and K fertilizer doses of 0, 50, and 100 kg K_2O ha^{-1} as well as the main effect of the two was not significant on the weight of 1000 rice grain grains. The weight of 1000 grains indicates the quality of the grain (grain size), which is determined by the number of components making up the grain, namely the amount of photosynthate produced.

Potassium is functional, so the function of K in increasing the weight of 1000 grains depends on the amount of photosynthate produced. If the elements needed in photosynthesis are not fulfilled, then giving large amounts of K will also not affect the process of photosynthesis.

Ismuhadi (2020) reported that giving KCl fertilizer doses of 100, 200, and 300 kg ha^{-1} had no significant effect on increasing the weight of 1000 sorghum seeds aged 15 WAP. Sirait (2017) reported giving rice husk ash at doses of 2.5, 5.0, and 7.5 Mg ha^{-1} showed no significant difference in the weight of 1000 grains of grain.

The Weight of Milled Dry Grains per Clump

Table 7 shows that the combination value of giving rice husk zeolite doses of 0, 200, and 400 kg ha^{-1} with K fertilizer doses of 0, 50, and 100 kg K_2O ha^{-1}, respectively was not significant as well

Table 6. The percentage of filled grain of upland rice was treated with rice husk zeolite and K fertilizer.

Rice husk zeolite dose (kg ha^{-1})	K Fertilizer dose (kg K_2O ha^{-1})			Average
	0	50	100	
		……%…..		
0	76.96 a	76.22 a	80.05 a	77.74 a
200	82.16 a	88.07 a	80.20 a	83.47 a
400	85.98 a	87.45 a	79.07 a	84.16 a
Average	81.70 a	83.91 a	79.77 a	

Note: Numbers in the same row and column followed by the same lowercase letters are not significantly different according to the DNMRT test at the 5% level.

Table 7. The weight of 1000 filled grains of upland rice was treated with rice husk zeolite and K fertilizer.

Rice husk zeolite dose (kg ha^{-1})	K Fertilizer dose (kg K_2O ha^{-1})			Average
	0	50	100	
		……g…..		
0	21.51 a	21.79 a	22.03 a	21.77 a
200	22.13 a	22.02 a	22.33 a	22.16 a
400	22.04 a	23.19 a	22.18 a	22.47 a
Average	21.89 a	22.33 a	22.18 a	

Note: Numbers in the same row and column followed by the same lowercase letters are not significantly different according to the DNMRT test at the 5% level.

Table 8. The weight of milled dry grain per clump of upland rice plants treated with rice husk zeolite and P fertilizer.

Rice husk zeolite dose (kg ha^{-1})	K Fertilizer dose (kg K_2O ha^{-1})			Average
	0	50	100	
		……g…..		
0	37.08 a	45.09 a	34.43 a	43.06 a
200	45.71 a	49.04 a	43.72 a	41.96 a
400	43.94 a	48.59 a	40.81 a	44.44 a
Average	42.24 a	47.57 a	39.65 a	

Note: Numbers in the same row and column followed by the same lowercase letters are not significantly different according to the DNMRT test at the 5% level.

as the main effect of rice husk zeolite, and fertilizer K on the weight of dry milled grain per clump, but in the combination value of giving rice husk zeolite at a dose of 200 kg ha^{-1} and K fertilizer at a dose of 50 kg K2O ha^{-1} tends to increase the weight of dry milled grain per clump of upland rice plants by 32.25% when compared without rice husk zeolite and K fertilizer.

The increasing is closely related to the role of zeolite, in which the provision of nutrients can increase available nutrients because they are absorbed by the zeolite and utilized in the photosynthesis process (producing photosynthate) so that during the generative phase, the results of the photosynthate produced can be utilized with the help of the role of K which plays a role in translocation, carbohydrate metabolism and as an enzyme cofactor (Wiraatmaja, 2016). Photosynthate produced in photosynthesis will be translocated to grain and metabolized into grain components (starch, protein, fat), in which K acts as an enzyme cofactor (activator of most enzymes). Wijaya's research (2023) showed an increase in the weight of dry milled grain per clump treated with zeolite fly ash 100-300 kg ha^{-1} of around 82,59% - 106,19% compared to no zeolite. Putri's research (2020) [Belum ada pada references] showed an increase in the weight of dry milled grain per clump by 31,93% compared to without zeolite.

CONCLUSIONS

The combination value of rice husk zeolite at a dose of 200 kg ha^{-1} and K fertilizer at a dose of 50 kg K2O ha^{-}1 tends to increase the number of green grains per panicle by 21%, the percentage of brown rice grain by 14% and the weight of dry milled grain by 32.25% compared without rice husk zeolite and K fertilizer.

The primary treatment of K2O ha^{-1} with a dose of 50 kg K2O ha^{-1} accelerated the aging of the panicles and harvest of upland rice plants when compared without K fertilizer or with the treatment of K fertilizer with a dose of 100 kg K2O ha^{-1}.

The primary treatment of rice husk zeolite at a dose of 200 kg ha^{-1} accelerated the aging of panicle exit and harvest of upland rice plants compared to without rice husk zeolite.

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