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EFFECTIVENESS OF LIQUID NPKSi AND N, P, K FERTILIZER ON NUTRIENT UPTAKE AND YIELD OF RICE PADDY IN ULTISOLS

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ABSTRACT

Agricultural intensification and extensification need to be done to increase rice productivity. Silicon (Si) is a non-essential nutrient that plays a positive role in growth and yield. The application of liquid NPKSi fertilizer increases nutrient availability, particularly on Ultisols. The purpose of this study was to assess the effectiveness of liquid NPKSi fertilizer and straight fertilizer on nutrient uptake and yield of paddy rice on Ultisols. This research was conducted from September 2023 to June 2024 at the Soil Fertility and Plant Nutrition Experimental Farm and the Soil Chemistry and Plant Nutrition Laboratory. This study used a Randomized Block Design (RBD), which consisted of nine treatments and three replications. The treatments included control, recommended N, P, and K fertilizers, and various doses of liquid NPKSi fertilizer and straight fertilizer. The results showed that liquid NPKSi fertilizer and straight fertilizer were effective in increasing nutrient uptake and yield of paddy rice on Ultisols. The highest fertilizer effectiveness was found in the treatment of 6 L.ha-1 liquid NPKSi fertilizer and straight fertilizer (175 kg.ha-1 Urea, 37.5 kg.ha-1 SP-36, and 25 kg.ha-1KCl) with an RAE value of 218%.

Keywords: Extensification, Fertilization, Intensification, Silicon.

1. INTRODUCTION

Indonesia has a humid tropical climate with high temperatures and rainfall, leading to soil weathering and leaching of base cations [1]. Ultisols, one of the most common soil orders, cover about 20-30% of Indonesia's land area, particularly in regions with high rainfall. These soils are highly weathered, leached, acidic, and have low base saturation, resulting in low Si bioavailability [2]. Silica enhances nutrient accumulation by increasing the availability and accumulation of macronutrients like N, P, K, Ca, and S [3]. Rice, a plant that can grow on Ultisols, faces challenges due to limited P availability, as it is retained by Fe oxides, making it inaccessible to plants. Furthermore, rice cultivation reduces Si availability over time, which is critical as Si competes with P for binding sites on Fe oxides and influences the release of available P [4]. Therefore, proper Si management is essential to mitigate P deficiency in rice soils, enhancing sustainability in rice production. To increase the productivity of Ultisols, soil improvement, fertilization, and organic matter addition are necessary.

Silicon is the second nutrient found in the earth's crust that can be utilized in agriculture to increase the productivity of Ultisols. Although not essential, Si supports plant growth, especially for Poaceae plants [5]. Silicon can also change soil properties by modifying water and air regimes, increasing the amount of nutrients (N, P, K), increasing soil pH, reducing heavy metal toxicity, and forming new silicate complexes [6], [7].

Liquid NPKSi fertilizer is a compound fertilizer that contains the three main macronutrients needed by plants (N, P, and K) with the addition of Si as a beneficial nutrient that can be applied in one fertilization. NPKSi fertilizer is used in liquid form because it is more easily absorbed by plants, and its application can be done together with water application through irrigation. Based on the results of research by Sugiyanta et al. [8], it is known that the application of liquid fertilizer Si 6 $L.ha^{-1}$ has an effect on increasing plant height and the number of tillers. This study aims to assess the effectiveness of liquid NPKSi fertilizer and straight fertilizer on nutrient uptake and yield of paddy rice on Ultisols.

2. MATERIALS AND METHODS

2.1 Location

The research was conducted from September 2023 to June 2024. The research was conducted at the Soil Fertility and Plant Nutrition Experimental Farm, Faculty of Agriculture, Padjadjaran University at an altitude of ± 750 masl. Fertilizer, soil chemistry, and plant analysis were conducted at the Soil Chemistry and Plant Nutrition Laboratory of the Department of Soil Science and Land Resources, Faculty of Agriculture, Universitas Padjadjaran. The soil samples used were paddy field soil from Jasinga District, Bogor Regency.

2.2 Experimental Design

This study used a Randomized Block Design (RBD) consisting of nine treatments with three replications with the following treatments:

Table 1: Research Design of Liquid NPKSi Fertilizer and Straight Fertilizer

Code	Treatment	Fertilizer Rate			
		$L.ha^{-1}$	$kg.ha^{1}$		
		Liquid NPKSi	Straight N, P, K		
			Urea	SP-36	KCl
A	Control negative (No fertilization)	0	0	0	0
B	Control positive (1 N, P, K)	0	350	75	50
C	½ Liquid NPKSi + ½ N, P, K	3	175	37.5	25
D	1 Liquid NPKSi + ½ N, P, K	6	175	37.5	25
E	1½ Liquid NPKSi + ½ N, P, K	9	175	37.5	25
F	½ Liquid NPKSi + 1 N, P, K	3	350	750	50
G	1 Liquid NPKSi + 1 N, P, K	6	350	750	50
H	1½ Liquid NPKSi + 1 N, P, K	9	350	750	50
I	2 Liquid NPKSi	12	0	0	0

Note: Liquid NPKSi fertilizer contains 12% N, 6% P_2O_5, 10% K_2O, and 5% SiO_2

2.3 Experimental Setup

Liquid NPKSi fertilizer was made by mixing micro-nutrients (ammonium heptamolybdate, $MnSO_4$, $CuSO_4$, and $ZnSO_4$) and macro-nutrients (Urea, $FeSO_4$, KCl, boric acid, KH_2PO_4, and EDTA), which were then dissolved with distilled water to a volume of 1 L. Inpari 48 rice seeds were used in this study. A total of 10 kg of Ultisol paddy soil was collected, loosened, and flooded in preparation for planting.

During transplanting, three seedlings were planted per bucket. After 14 DAS, thinning was performed, leaving only one plant per bucket to identify seedlings with the best growth potential, while the remaining plants were buried in the soil to replenish the nutrients that had been taken up. Irrigation was carried out from one day old rice plants onwards to maintain nutrient availability.

Plant analysis was conducted at the maximum vegetative phase, around 67 DAS, characterized by the appearance of flag leaves and booting stage. The necessary plant part for nutrient uptake measurement was the shoot. Harvesting was carried out when 90-95% of the grains in the panicle were yellow or golden yellow, approximately 30-35 days after the panicle flowers.

2.4 Parameters and Statistical Analysis

Nitrogen uptake was measured by the Kjeldahl method of wet ignition with H_2SO_4. Phosphorus and potassium uptake were measured by the wet ignition method with HNO_3 and $HClO_4$. Silicon uptake was measured by dry sowing and acid digestion methods. Rice yield was expressed in milled dry grain (MDG). All data were analyzed by analysis of variance ($P<0.05$). If the treatment had a significant effect on the parameters, further tests were conducted with DMRT (Duncan Multiple Range Test) using IBM SPSS Statistic 26. The RAE value was calculated to determine the effectiveness of liquid NPKSi fertilizer and straight fertilizer with the following equation:

$$\text{RAE} = \frac{\text{yield of fertilizer tested} - \text{yield of control fertilizer}}{\text{yield of standard fertilizer} - \text{yield of control fertilizer}} \times 100\%$$

3. RESULTS AND DISCUSSION

3.1 Nutrient Uptake

Based on Table 1, the application of liquid NPKSi and N, P, K fertilizers resulted in nutrient uptake of paddy rice that varied depending on the type of nutrient. The results of analysis of variance showed that the treatment of liquid NPKSi fertilizer and straight fertilizer significantly affected the uptake of N, P, K, and Si of paddy rice. In general, the treatment of ½ liquid NPKSi and 1 N, P, K was significant in N, P, and K (0.65, 0.17, and 0.39 $g.pot^{-1}$), except Si which was significant in the treatment of ½ liquid NPKSi and ½ N, P, K (0.67 $g.pot^{-1}$).

Table 2. Effect of Liquid NPKSi and N, P, K Fertilizer on Nutrient Uptake

Treatment		Uptake ($g.pot^{-1}$)			
		N	P	K	Si
A	Control negative (No fertilization)	0.06a	0.07a	0.05a	0.27ab
B	Control positive (1 N, P, K)	0.23ab	0.08ab	0.13a	0.36abc
C	½ Liquid NPKSi + ½ N, P, K	0.54bc	0.14bc	0.20a	0.67d
D	1 Liquid NPKSi + ½ N, P, K	0.31ab	0.13abc	0.17a	0.42abcd
E	1½ Liquid NPKSi + ½ N, P, K	0.34ab	0.15c	0.18a	0.48bcd
F	½ Liquid NPKSi + 1 N, P, K	0.65c	0.17c	0.39b	0.63cd
G	1 Liquid NPKSi + 1 N, P, K	0.24ab	0.12abc	0.13a	0.33ab
H	1½ Liquid NPKSi + 1 N, P, K	0.46bc	0.16c	0.19a	0.16a
I	2 Liquid NPKSi	0.34ab	0.15c	0.21a	0.50bcd

Notes: same letter behind the number indicates not significantly different according to Duncan's Multiple Range Test at 5% real level

The role of N and K fertilizers in increasing N and K uptake in paddy rice is very important. Urea, as a high concentration N source of 46%, and KCl, as a K source of 50% concentration, are more efficient in providing N and K to plants, thus supporting increased N and K uptake compared to NPKSi fertilizer which contains only 12% N and 10% K. These higher nitrogen levels promote dry matter production, N uptake, yield, and yield components in rice, while higher potassium levels increase biomass accumulation, K concentration, and rice yield [9], [10].

Liquid NPKSi fertilizer also has an important role in increasing N and K uptake in paddy rice due to the presence of Si. Application of ½ dose of liquid NPKSi significantly increased N and K uptake compared to the application of a straight fertilizer independently. Silicon in liquid NPKSi contributes to plant cell wall strengthening and enhanced root growth, which increases the capacity of plants to absorb and use nitrogen from straight fertilizer [11]. In addition, the cell wall silicification process stimulates the activation of H^+-ATPase in the membrane, which may explain the increased K uptake [12].

Application of Si in the form of monosilicic acid can increase P concentration, making it more soluble and available to plants [13]. This may be due to increased P solubility and decreased soil P retention capacity [12]. By reducing P retention capacity, an ideal Si application may have increased P availability and solubility, resulting in greater root development and P use efficiency [14]. The addition of silicate materials may also affect the enhancement of Si uptake. Application of Si fertilizer can increase soil Si availability and improve the root system, allowing plants to absorb more Si from the soil solution [14]. In addition, the application of N [15], P [16], and K [17] fertilizers can also increase Si uptake in paddy rice.

3.2 Rice Yield

The average yield of paddy rice and its RAE value are presented in Table 3. The results of the analysis of variance showed that the liquid NPKSi and straight fertilizer treatments significantly affected the MDG. In general, the NPKSi liquid and straight fertilizer treatments were not significantly different from the positive control treatment, except for the 1 NPKSi liquid and ½ straight fertilizer treatment. The highest RAE value was found in the treatment of 1 NPKSi liquid and ½ straight fertilizer, followed by the treatment of ½ NPKSi liquid and ½ straight fertilizer.

Table 3. Rice Yield and Relative Agronomic Effectiveness (RAE) values of paddy rice on Ultisols

Treatment		Yield	RAE
		MDG t.ha^{-1}	%
A	Control negative (No fertilization)	2.77a	
B	Control positive (1 N, P, K)	5.84ab	100
C	½ Liquid NPKSi + ½ N, P, K	7.49bc	154
D	1 Liquid NPKSi + ½ N, P, K	9.43c	218
E	1½ Liquid NPKSi + ½ N, P, K	6.53bc	-49
F	½ Liquid NPKSi + 1 N, P, K	6.46bc	102
G	1 Liquid NPKSi + 1 N, P, K	6.79bc	-371
H	1½ Liquid NPKSi + 1 N, P, K	3.93ab	-767
I	2 Liquid NPKSi	7.31bc	-18

Notes: same letter behind the number indicates not significantly different according to Duncan's Multiple Range Test at 5% real level

The application of 1 NPKSi liquid and ½ straight fertilizer resulted in an MDG of 9.43 t.ha-1. This affects the effectiveness of fertilizer which can be evaluated from the RAE value. Low to medium doses of liquid NPKSi together with low doses of recommended fertilizers can replace full doses of recommended fertilizers, while providing Si which increases rice yield. However, as the dosage increases both become ineffective due to nutrient imbalance. Therefore, it is important to find the right ratio between liquid NPKSi and a straight fertilizer so that plants absorb nutrients optimally and thus increase yield.

4. CONCLUSION

The Application of liquid NPKSi fertilizer together with a straight fertilizer can increase the uptake of N, P, K, and Si and rice yield on Ultisols. The agronomic effectiveness of liquid NPKSi fertilizer application of 6 L.ha^{-1} and straight fertilizer (175 kg.ha^{-1} Urea, 37.5 kg.ha^{-1} SP-36, and 25 kg.ha^{-1} KCl) was greater than other liquid NPKSi fertilizer treatments and NPK recommendations on Ultisols, which was 218%.

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