Effect of NPK, and Si Fertilizers on Exchangeable Potassium, K Uptake and Growth of Black Rice (*Oryza sativa* L. indica) on Ultisols

Anni Yuniarti[1], *Eso* Solihin[1], *Alifia* Syifa Alzena Wibowo[2], *Saedi* Bawana[1*]

[1] Department of Soil Science and Land Resources, Faculty of Agriculture, Padjadjaran University, Jatinangor, Indonesia, 45360
[2] Student of the Agrotechnology Study Program, Faculty of Agriculture, Padjadjaran University, Jatinangor, Indonesia, 45360

Abstract. Ultisols are one of the soil orders that dominate dry land in Indonesia, and they have a lot of fertility issues. NPK and Si fertilization is used to enhance soil conditions and deliver nutrients to plants. Jeliteng cultivar black rice is a type of rice that can be cultivated on dry land. This research was conducted from October 2021 to January 2022 at the Experimental Land for Soil Chemistry and Plant Nutrition, Faculty of Agriculture, Universitas Padjadjaran, Jatinangor, West Java with an altitude of 750 meters above sea level. The experimental design was carried out using a Randomized Block Design with nine treatments and three replications. The results showed that the combination of 1 NPK + 1 Silica fertilizer was the best treatment in increasing the exchangeable potassium of the soil, which was 0.70 cmol.kg^{-1} and K uptake was 1.91 mg/tanaman. There is no one best treatment dose for plant growth, but the addition of NPK, and Si fertilizers, can increase plant growth, specifically plant height and number of tillers.

1 Introduction

Soil is a planting medium that absorbs nutrients and oxygen from rice roots, which is where rice grows. The large number of plant products transported from the soil has an impact on the depletion of the macro-soil nutrients (C; H; O; N; P; K; Mg; Ca; S) as well as soil micronutrients (B; Cu; Zn; Fe; Mo; Cl; Co) over time [15]. Supplementation of liquid NPK and Si fertilizers to the soil aims to maintain and increase soil fertility. In addition, the utilization of fertilizers also increases the availability of soil exchangeable potassium and plant uptake in the soil.

Indonesia as an agricultural country certainly has abundant agricultural land. Ultisol dry land is common in Indonesia which covers around 25% of the total land area [10]. Ultisols are old soils that have poor physical properties, namely low water holding capacity, clayey clay texture, and lower permeability [8]. The problem with Ultisols is that the soil is acidic (pH 3.8-5.7) with lesser nitrogen, phosphor, potassium, calcium and magnesium [7].

[*] Corresponding author: saedibawana@gmail.com

https://doi.org/10.1051/e3sconf/202344404027

The nutrients contained in Ultisol are low. Ultisols are soils that have acidic soil properties with lesser organic matter macronutrients especially phosphor [5]. The availability of potassium for plants depends on plants, climate, and soil conditions such as the amount and type of cation exchange capacity (CEC); soil buffering capacity against K; clay minerals; humidity; soil pH; temperature; aeration. Al saturation in Ultisol is very high, this will affect the situation of plants and soil planted in the soil.

Rice is one of the superior agricultural commodities in Indonesia and is the main source of food for the population. Black rice (*Oryza sativa* L. indica) has many benefits because it contains high anthocyanins. As population growth and public awareness of the benefits and availability of rice are still a top priority for meeting food needs, this has an effect on increasing demand for rice.

Si nutrients in liquid form function as ameliorants which expected help to increase the dry weight of straw and the amount of grain, improve P availability in P-deficient plants, reduce the number of empty grains and increase grain weight, as well as increase plant resistance to disease [1]. Deficiency of Si can cause plants to become more susceptible to attack by pests, fungal diseases, and abiotic stresses which adversely affect rice yield and quality [14].

Based on the description of the background, it is expected that supplementation of NPK, and Si can increase exchangeable potassium, K uptake also the growth of black rice in Ultisols from Jasinga.

2 Methodology

The experiment was conducted at Jatinangor, Sumedang Regency by an latitude of ±752 m above the sea level from October 2021 to Januari 2022. Chemical analysis was taken out in Chemistry Laboratory Soil and Plant Nutrition Deoartment of Soil Science and Land Resource, Faculty Agriculture, Padjadjaran University.

This experiment applicate the material were the black rice sepeda from local Jeliteng type, planting media soil shaped from the order Ultisol from Jasinga, zeolite as a basic fertilizer, inorganic fertilizer Urea (46% N), SP-36 (36% P_2O_5), KCl (50% K_2O), and liquid Si (19.90% SiO_2) with various doses according to the treatment and chemicals for soil and plant analysis tests in the laboratory.

This experiment using the RBD or Rabdomized Block Design. The treatment was arranged as many as 9 treatments consisting of: A = control (without NPK and the Si fertilizer; B = 1 NPK without Silica; C=1; G=¾ NPK +1½ Silica; H=¾ NPK + 2 Silica; and I = Without NPK + 2 Silica.

Every treatment replicated three times until there were 27 experimental unit. Black rice id planted on dry land using some polybag which size is 40x40 cm with a distance between that is 25x25 cm. Conduct a normality test on the data obtained to see if the data distribution follows the normal or not. The treatment's effect can be seen by the way the data is processed statistically with the SPSS version 22 program with the F test at the 5% significance level. significant 5% to be able to know the average difference between treatments and to determine the best treatment.

The variables observed included soil exchangeable potassium, K absorption and black rice plant growth height's plan shaped and tillers' number. Soil sampling for soil exchangeable potassium and K uptake tests was carried out when the plants reached the maximum vegetative phase.

3. Result and Discussion

3.1 Exchangeable Potassium

The results of statistical tests showed that supplementation of NPK and the Si fertilizers have signficant impact to the soil.

Table 1. The Effect of NPK, and Silica Fertilizers on the exchangeable potassium of Ultisol Soil.

Code	treatment	exchangeable potassium ($cmol.kg^{-1}$)
A	Control	0.04 a
B	1 NPK without Silica	0.18 bc
C	1 NPK + ½ Silica	0.22 d
D	**1 NPK + 1 Silica**	**0.70 e**
E	1 NPK + 2 Silica	0.22 d
F	¾ NPK + 1 Silica	0.16 b
G	¾ NPK + 1½ Silica	0.20 cd
H	¾ NPK + 2 Silica	0.21d
I	without NPK + 2 Silica	0.15 b

Note: The letters that follow the numbers don’t represent the difference in pursuance of the DMRT at 5% significance level.

As maintained on the Table 1, supplementation of NPK and Si fertilizers can increase the soil exchangeable potassium content, but in the control treatment it has no effect on increasing soil exchangeable potassium. In the control treatment, it decreased based on the intial soil analysis result of 0,11 $cmol.kg^{-1}$ to the 0,04 $cmol.kg^{-1}$. This is caused by the absence of the addition of other nutrients in the control treatment so that the K nutrient in the soil is not fulfilled.

The treatment of 1 NPK and 1 dose of Silica has the highest exchangeable potassium value of 0.70 $cmol.kg^{-1}$ and significantly different from other treatments. Supplementation of NPK and Si fertilizers can increase exchangeable potassium as seen in the exchangeable potassium value which increased in the initial soil by 0,11 $cmol.kg^{-1}$ to the 0,70 $cmol.kg^{-1}$ in the 1 NPK + 1 Silica treatment, so that the treatment with fertilizer input of 1 NPK + 1 Silica was the highest treatment result among the other treatments and the control treatment was the lowest treatment with a exchangeable potassium value of 0.04 $cmol.kg^{-1}$. The provision of Si in plants causes the system of roots to improve when it got more strengthness to making them even more effective to absorb the nutrients [12].

The increase in exchangeable potassium was directly influenced by the addition of NPK and Si fertilizers, the higher the dose of N,P,K fertilizer given, the higher the value of exchangeable potassium in the soil [2]. Plants will absorb K nutrients available in the soil from fertilization and organic matter from the decomposition of compounds in the soil.

Fertilizer application will increase K levels in solution, causing K to be absorbed to increase and its availability to plants also increase [9]. Nutrients absorbed by plants will have an impact on reducing the available soil’s nutrients so that the fertilization and doses given will affect the availability/existence of soil’s nutrients.

3.2 K uptake

Statistical test results showed that supplementation of NPK and Si have signficant impact to the K absorb. Based on Table 2, supplementation of NPK and Si fertilizers can increase K uptake, but in the control treatment it has no effect on increasing K uptake with a K uptake value of 0.68 mg.plant^{-1}. This is caused by the absence of the addition of other nutrients in the control treatment so that the K nutrient in the soil is not fulfilled.

Table 2. The Effect of NPK, and Silica Fertilizers on Black Rice Plant K Uptake in Soil

Code	Treatment	Potassium uptake (mg.plant^{-1})
A	Control	0.68 a
B	1 NPK without Silica	1.43 cd
C	1 NPK + ½ Silica	1.46 cd
D	**1 NPK + 1 Silica**	**1.91 e**
E	1 NPK + 2 Silica	1.48 d
F	¾ NPK + 1 Silica	1.29 bcd
G	¾ NPK + 1½ Silica	1.40 cd
H	¾ NPK + 2 Silica	1.16 bc
I	without NPK + 2 Silica	1.03 c

Note: The letters that follow the numbers don't represent the difference in pursuance of the DMRT at 5% significance level.

Supplementation of NPK and Si fertilizers with a treatment dose of 1 NPK + 1 Silica resulted in the highest treatment yield of K uptake among the other treatments, namely 1.91 mg.plant^{-1} and the control treatment became the lowest treatment with an absorption value K of 0.68 mg.plant^{-1}. This is because K absorption was impacted by the existence from K nutrients in soil through fertilization. Fertilization given to NPK, and Si fertilizers have signficant impact to the K uptake. Balanced fertilization showed the best results in this study. Potassium was saturated by the plants in K+ ions shaped and functions to support plant metabolic processes [17].

The increase in K uptake was affected by the increase in the dose of NPK fertilizer given, K uptake was positively correlated with exchangeable potassium, the greater the exchangeable potassium, the greater the plant's K uptake. It has been known that the amount absorbed by plants is specified by the concentration of K in the soil solution, if the concentration of K in the soil is high, the K uptake of plants will also be high [16]. Supplementation of potassium fertilizer to plants affects the availability of K in the soil. It has been known that the K fertilizer's use is given in moderation as needed, if the excess K absorbed by plants will be less beneficial for increasing growth or yield resulting in wastage of fertilizer [13].

The addition of Si fertilizer also plays a role in increasing K uptake by support the root growth. Silica application to the soil helps strengthen the root, so that nutrient absorption will be accelerated and the nutrient requirements needed by plants can be fulfilled.

3.3 Plant Growth

3.3.1 Black Rice Plant Height

Statistical test result showed that supplementatuon from NPK and Si fertilizers had a substansial impact to the plant height. As maintained on Table 3, the plant height with the control treatment, namely with a yield of 46.17 cm, wasn't signficantly different to the 1 NPK treatment without Silica, the 1 NPK + ½ Silica treatment and the treatment Without NPK + 2 Silica. This is because in the control treatment there was no addition of other nutrients through fertilization, so that nutrient availability affected the rice plant height. Fertilization with unbalanced doses affects plant height because the nutrients needed by plants must be fulfilled, excess or deficiency of nutrients will affect plants. Plants that are deficient in N and P nutrients will affect plant height to become stunted, whereas if plants have an excess of N nutrients it will affect plant stems to become weak so that plants fall easily [6].

Table 3. Effect of NPK, and Silica Fertilizers on the Height of Black Rice Plants aged 9 WAP on Ultisol Soil

Code	treatment	Plant height (cm)
A	Control	46.17 a
B	1 NPK without Silica	55.33 abc
C	1 NPK + ½ Silica	55.17 abc
D	**1 NPK + 1 Silica**	**63.73 c**
E	1 NPK + 2 Silica	60.37 c
F	¾ NPK + 1 Silica	56.57 bc
G	¾ NPK + 1½ Silica	57.13 bc
H	¾ NPK + 2 Silica	58.87 c
I	without NPK + 2 Silica	47.63 ab

Note: The letters that follow the numbers don't represent the difference in pursuance of the DMRT at 5% significance level.

The 1 NPK + 1 Silica treatment with a yield of 63.73 cm wasn't signficantly different to the 1 NPK treatment without Silica with a yield of 55.33 cm, the 1 NPK + ½ Silica treatment with a yield of 55, 17 cm, treatment of 1 NPK + 2 Silica with a yield of 60.37 cm, treatment of ¾ NPK + 1 Silica, namely with a yield of 56.57 cm, treatment of ¾ NPK + 1 ½ Silica, namely with a yield of 57.13 cm, treatment of ¾ NPK + 2 Silica, namely with a yield of 58.87 cm. It can be seen in Table 4 that 1 NPK + 1 Silica treatment yielded 63.73 cm, 1 NPK + 2 Silica treatment yielded 60.37 cm and ¾ NPK + 2 Silica treatment, namely with a yield of 58.87 cm gave significantly different results to the control treatment with a yield of 46.17 cm and the treatment Without NPK + 2 Silica with a yield of 47.63 cm. Supplementation of NPK and Silica fertilizers at the right doses showed a significant effect on black rice plant height compared to the treatment without fertilizer.

The inorganic fertilizers given can provide the nutrients needed by plants so that they can support plant growth and cause metabolic processes in plants to run well. The fulfilled NPK and Si nutrients will play a role in triggering plant growth. The addition of nutrients can accelerate the growth of stems and leaves, this is followed by the effect of high growth on plants given inorganic fertilizers with adequate and appropriate doses compared to treatments that are not given fertilizer or with fertilizers that are not fulfilled [11].

The presence of silica in the soil can cause nutrient absorption to be more optimal so that there is an increase in photosynthetic efficiency. The componenr Si existed as a main role in stem elongation, with the presence of Si accumulating in the leaves causing the leaves to stretch properly and become more upright thus helps the plants absorb the sunlight. The process of plant growth requires sunlight, so that the plant stems will become taller [12].

3.3.2 Number of black rice plant tillers

Statistical test result proved that the supplementation from NPK and the Si fertilizer had a crucial impact to the tillers' number. The result from statistical test analysiss at the rice plants' tiller numbers in Table 4 shows about the NPK's treatment and the Si fertilizers has an impact to the rice plants and tiller number. There is a difference in that number that given N,P,K and the Si fertilizers with the rice plants' tillers' number that are not given that four fertilizers.

Table 4. Effect of NPK, and Silica Fertilizers on the number of tillers of black rice plants aged 9 WAP on Ultisols

Code	treatment	black rice plant tillers
A	Control	15.33 a
B	1 NPK without Silica	45.67 b
C	1 NPK + ½ Silica	47.67 b
D	**1 NPK + 1 Silica**	**57.67 b**
E	1 NPK + 2 Silica	56.00 b
F	¾ NPK + 1 Silica	42.00 b
G	¾ NPK + 1½ Silica	50.00 b
H	¾ NPK + 2 Silica	53.33 b
I	without NPK + 2 Silica	17.67 a

Note: The letters that follow the values don't represent the difference in pursuance of the DMRT at 5% significance level.

The number of tillers in the control treatment and the treatment without NPK + 2 Silica with results of 15.33 and 17.67 showed significantly different values from the other treatments (Table 4). The control treatment and the treatment without NPK + 2 Silica were the lowest treatment. This was due to the absence of the addition of other nutrients through fertilization in the control treatment, so that the nutrient availability in the control treatment was lower compared to other treatments given fertilizer. The absence of fertilizer application affects the number of tillers of rice plants which is low from the treatment given fertilizer. Plant needs are also met by applying NPK and Si fertilizers. Unfulfilled fertilization, such as treatment without NPK and Si, also causes plant needs to be unfulfilled which affects the number of tillers of rice plants.

Rice plants in the treatment with NPK and Silica fertilizers showed tillers' number that more high opposed to the treatment control and the treatment without the N,P,K. This was due to addition of nutrients through NPK, and K fertilizers. Si which can be absorbed directly by plants compared to the control treatment and treatment without NPK + 2 Silica, that is, the nutrient requirements needed by plants are not fulfilled, so the results are not optimal.

Nitrogen nutrients affect the vegetative growth of rice plants, especially in the number of tillers which becomes large and the development of leaves [4]. In plants, the nutrient N has a role in the preparation of chlorophyll, amino acids, nucleic acids and nucleotides to encourage plant growth, namely the number of tillers and the formation of branches [3].

The element silica isn't entered to the plants' essential nutrients, but Si provides the useful impacts for many plants. Si fertilizers can intensify the tillers number, this is because the hoarding of assimilated through our the photosynthesis mechanism can intensify the tillers number [18]. Supplementation of Si fertilizer also affects the increase in P uptake which results in the number of tillers also increasing because phosphorus is wanted by the plants in division cells process and existed as an energy at all plants metabolic mechanism [19].

4 Conclusions

1. Supplementation of NPK and Si fertilizers had an effect on soil exchangeable potassium and K uptake in the growth of black rice which included the height of plant and the number of tillers in Ultisol soil.
2. The combination of 1 NPK fertilizer (250 kg Urea, 100 kg SP-36 and 100 KCl) + 1 Silica (2 mL/L water) is the best treatment in increasing soil exchangeable potassium, namely 0.70 cmol.kg^{-1} and K uptake is 1.91 mg.plant^{-1}. There is no single treatment dose that is the best for plant growth, but the supplementation of Si fertilizers increased plant growth, namely plant height and number of tillers.

References

1. Agustiansyah. 2017. Pengaruh Pemberian Silika dan Mangan Terhadap Mutu Fisiologis Benih Padi (*Oryza sativa* L.) Yang Dihasilkan. Agrovigor. **10**(1), 44-48.
2. Amorita, W., Nurbaity, A., & Herdiyantoro, D. 2016. Pengaruh Dosis Pupuk Npk Dan Ordo Tanah Terhadap Kdd, Serapan K, Dan Hasil Bibit Kentang (*Solanum tuberosum* L.) Yang Diinokulasi Fungi *Mikoriza Arbuskula* dan *Mycorrhiza Helper Bacteria*. Soilrens, **14**(2).
3. Badan Litbang Pertanian. 2015. Manfaat Unsur N, P, dan K bagi Tanaman. BPTP Kaltim.
4. Cahyono, Y., Wijayanto, Y., & Hermiyanto, B. 2019. Prediksi Hasil Tanaman Padi Berdasarkan Input Nitrogen Dengan Simulasi Model Cropsyst Di Kecamatan Mayang. Jurnal. Il. Tan. Lingk., 58-65
5. Fitriatin, B. N., A. Yuniarti., T. Turmuktini., dan F. K. Ruswandi. 2014. *The Effect of Phosphate Solubilizing Microbe Producing Growth Regulators on Soil Phosphate, Growth and Yield of Maize and Fertilizer Efficiency on Ultisol. Eurasia.* J. of Soil Sci. Indonesia. Hal 101-107.
6. Hardjowigeno, S. 2010. Ilmu Tanah. Akademik Pressindo. Jakarta
7. Kasno, A. 2019. Perbaikan Tanah Untuk Meningkatkan Efektivitas Dan Efisiensi Pemupukan Berimbang Dan Produktivitas Lahan Kering Masam. Jurnal Sumberdaya Lahan, **13**(1), 27-40.
8. Meli, V., Sagiman, S., & Gafur, S. 2018. Identifikasi Sifat Fisika Tanah Ultisols Pada Dua Tipe Penggunaan Lahan Di Desa Betenung Kecamatan Nanga Tayap Kabupaten Ketapang. Perkebunan dan Lahan Tropika, **8**(2), 80-90.
9. Nursyamsi, D. 2006. Kebutuhan Hara Kalium Tanaman Kedelai Di Tanah Ultisol. Jurnal Ilmu Tanah dan Lingkungan, **6**(2), 71-81.
10. Prasetyo, B. H., & Suriadikarta, D. A. 2006. Karakteristik, Potensi, Dan Teknologi Pengelolaan Tanah Ultisol Untuk Pengembangan Pertanian Lahan Kering Di Indonesia. Jurnal Litbang Pertanian, **25**(2), 39-46
11. Pramitasari, H., Wardiyati , T., & Nawawi, M. 2016. Pengaruh Dosis Pupuk Nitrogen Dan Tingkat Kepadatan Tanaman Terhadap Pertumbuhan Dan Hasil Tanaman Kailan (*Brassica oleraceae* L.). Jurnal Produksi Tanaman, 49-56.
12. Putri, F. M., Suedy, S. W. A., & Darmanti, S. 2017. Pengaruh Pupuk Nanosilika Terhadap Jumlah Stomata, Kandungan Klorofil dan Pertumbuhan Padi Hitam (*Oryza*

sativa L. *japonica*). Buletin Anatomi dan Fisiologi (Bulletin Anatomy and Physiology), **2**(1), 72-79.

13. Subandi, S. 2013. *Role And Management Of Potassium Nutrient For Food Production In Indonesia*. Pengembangan Inovasi Pertanian, **6**(1), 30881.
14. Sugiyanta, Dharmika, I., & Mulyani, D. 2018. Pemberian Pupuk Silika Cair Untuk Meningkatkan Pertumbuhan, Hasil, Dan Toleransi Kekeringan Padi Sawah. J. Agron. Indonesia, 153-160.
15. Suharno, S., Junianto, J., & Hasna, H. 2019. Respon Padi Hitam Dan Padi Ungu Pada Berbagai Pupuk Nitrogen Terhadap Daya Hasil, Kandungan Amilosa, Dan Kandungan Pati. Agrica Ekstensia, **13**(2), 1-8.
16. Suyono, A. D. 2008. Pupuk dan Pemupukan. Unpad Press. Bandung.
17. Winarso, S. 2005. Kesuburan Tanah. Gava Media. Yogyakarta.
18. Yohana, O. 2013. Pemberian Bahan Silika pada Tanah Sawah Berkadar P Total Tinggi untuk Memperbaiki Ketersediaan P dan Si Tanah, Pertumbuhan dan Produksi Padi (*Oryza sativa* L.) Jurnal Online Agroekoteknologi. **1**(4):1-9
19. Zulputra, Z., Wawan, W., & Nelvia, N. 2014. Respon Padi Gogo (*Oryza sativa* L.) Terhadap Pemberian Silikat Dan Pupuk Fosfat Pada Tanah Ultisol. Jurnal Agroteknologi, 1-10.