Effectiveness and efficiency of potassium fertilizer application to increase the production and quality of rice in entisols

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Abstract. The study aimed to determine the appropriate dose of K-type fertilizer on the production and quality of IR-64 rice varieties in Entisols. The study was conducted on Entisols, Nglarang, Basin, Kebonarum, Klaten, Central Java, Indonesia. Randomized Complete Block Design (RCBD) was used with 2 factors and three replicates. Factor I: types of K fertilizer: KCl, ZK, and KNO₃. Factor II: K fertilizer dose consists of four levels: 0, 50, 100 and 150 kg K₂O ha⁻¹. The results showed that the type of K fertilizer KCl, ZK, and KNO₃ gave similar effect on growth and yield of rice variety IR 64 on Entisols. Dose of K fertilizer increased the growth and yield of rice but an increased dose provides improved meaningful results. K fertilizer with a dose of 50 kg ha⁻¹ K₂O is the most efficient, with the agronomic efficiency for dry grain highest yield of 13.6 kg / kg K₂O achieved by ZK fertilizer.

1. Introduction
Rice is the staple food most of Indonesians, therefore, play a major role in the economic life and national politics. Indonesia's rice demand is around 32.947 million tons per year based on consumption of 139 kg per capita per year for a population to 237 million. If rice production is not increasing in 2030 there will be a shortage of rice by 26 million tonnes equivalent of 12 million hectares [1]. Constraints in increasing rice production including: weather anomalies that have the potential to climate change impact on water shortage [2], the rate of conversion of agricultural land [3][4], and a decrease in productivity intensification of land due to the changes in irrigation systems [5].

Potassium (K) contributes to [6][7] the quality and plant resistance to water stress because of lower transpiration so that water consumption is low [6]. K role in the process of transpiration or water transport within the plant body is as a regulator of cell osmotic potential [8][9]. Another opinion states that K plays a multifunctional: as activating enzymes, stimulating and transport of assimilates, a stabilizing anion or cation in the transport of water through stomatal movement. Likewise, some studies indicate that the addition of K fertilizer increases the number of branches cause on the crop yields [10]. Regosol soil generally contains enough elements of P and K which are still fresh and not ready to be absorbed by plants, but often lack of Nitrogen (N) [11]. On the other hand, Entisols is soil with low organic matter content and generally responsive to nitrogen fertilization [12]. The content of organic matter in soil Entisols is low and the land is vulnerable to erosion.
2. Methods
Research was conducted with experimental methods in wetland Regosol soil types, from April to November 2016. The experiment consists of two factors, types of fertilizers K (KCl, ZK, and KNO₃) and doses (0, 50, 100, and 150 kg K₂O ha⁻¹), in order to obtain 12 combined factorial treatments. The experimental design was a randomized complete block design (RCBD), any combination is repeated three times so that there are 36 experimental unit. Trial begins with processing the soil using hoes to the deep layers of silt (20 cm). This plot area is divided into three blocks (replications), the distance between blocks 50 cm. Each block is divided into 12 experimental unit (plot) measuring 2 x 2.5 m² each spaced 50 cm.

The planting of rice variety IR-64, carried out after the processing of land with a spacing of 25 x 25 cm and 5 seedlings per plot. The seedlings were obtained from the nursery were 18 days old. The day before planting dispersed Urea was given as basal fertilizer with a dose of 400 kg ha⁻¹ and SP 36 fertilizer 300 kg ha⁻¹. Potassium fertilizer is given once, Urea and SP-36 is given twice at the rest at the age of six weeks with appropriate doses of the treatment. Watering was done with land flooded as high as about 5 cm to 3-week-old plants, after it was drained, irrigated every 3 days. Weeding was done at the age of 2 weeks after planting manually. Pest control (dominant pest snails) was using pesticides, while for the disease although the infection does not occur pesticide spraying was conducted as a preventative measure. Harvesting was done after all the plants in one plot dries (visually brown), about 90 days old plants.

Data was collected with direct observations on plant height, counting the number of productive tiller, tiller number nonproductive and weighing of grain harvested dry weight and the weight of milled rice, as well as the weight of 1000 seeds. Laboratory analysis of the soil before planting consisted of: texture methods pipette, heavy volume gravimetric method, specific gravity (BJ) gravimetric method, organic matter content method of Walkley and Black, acidity (pH) method elektrometri (soil: H₂O = 2:5), the cation exchange capacity (CEC) method of saturation of ammonium acetate, N (Kjeldahl method), K (method of saturation of ammonium acetate), available P (method Bray 1), Ca (method of saturation of ammonium acetate), and Mg (method of saturation of ammonium acetate). Analysis of the soil after harvest were including pH, total N content, available P and K available. Data were analyzed using analysis of variance with 0.05 significance level (F-test). If significantly different treatment were found, Duncan multiple range test (DMRT) were done to confirm the difference between pairwise treatments. Relationships between variables were analyzed with Pearson’s correlation.

3. Results and Discussion

3.1 Initial soil conditions
The results of the analysis of baseline soils have physical and chemical properties as follows: BV 1.12 g cm⁻³, BJ 2.17 g cm⁻³, 48.89% sand, dust 33.80% and clay 15.31% that included loam, pH 6.85 (rather acid), CEC cmol 20.36 kg⁻¹ (moderate), total N 0.13% (low), available P 5.3 ppm (low), K available cmol 0.15 cmol kg⁻¹ (low), Ca 9.55 cmol kg⁻¹ (moderate) and 0.89 Mg cmol kg⁻¹ (low). Based on the chemical properties of the soil the content of macro nutrients needed crops including lower categories so it needs the input of fertilizer.

3.2 Last soil conditions
Diversity test results showed that the treatment had no effect on the final soil pH, soil total N content of the final, and the available soil P end with an average value of 7.38 in a row; 0.23% and 9.04 ppm. The test results showed that a wide diversity of K fertilizer had no effect on K provided soil and K fertilizers significantly affect K available and there was no interaction between the two. The results of the final analysis of available K presented by Table 1.

The test results showed that a wide diversity of K fertilizer, potassium fertilizer dosage and the interaction between them show the influences that are not significant. The results of initial soil
analysis showed a pH of 6.85. The provision of a wide range of K fertilizer on various doses of K fertilizer had lower soil pH value. A decrease in pH was due to the flooding.

### 3.3 Plant growth

Results of analysis of variance showed that the treatment effect on plant height. The types of fertilizer K and dose significantly affected plant height, while their interaction effect was not based. Based on Figure 1, on average fertilizer KCl give the best results (92.7 cm high) and not significant when compared with KNO3 fertilizer (90.7 cm), while ZK fertilizer low (88.7 cm).

**Table 1. The effect of Fertilizer K Dose to CEC and K available**

| Dose of K Fertilizer (kg K2O/ha) | CEC (cmol.kg⁻¹) | K available (cmol.kg⁻¹) |
|---------------------------------|----------------|------------------------|
| 0 kg K2O/ha                   | 19.17a         | 0.13a                  |
| 50 kg K2O/ha                  | 20.84b         | 0.19b                  |
| 100 kg K2O/ha                 | 22.27b         | 0.21bc                 |
| 150 kg K2O/ha                 | 23.31b         | 0.27c                  |

a,b,c Different superscripts indicated significant differences (P<0.05)

Analysis of the cation exchange capacity (CEC) of the soil and K available soil after harvest showed that types of fertilizers K influence was not evident, as well as their interaction effect was not significant. K fertilizer application significantly affected the CEC and K available in soil. The K fertilizer application was significantly different compared with K fertilizer to the soil CEC and K available land. With increasing doses of fertilizers applied improve both the CEC and K available in the soil. K fertilizer application dose of 50 kg K2O.ha⁻¹, 100 kg K2O.ha⁻¹ and 150 kg K2O.ha⁻¹ provides enhanced soil CEC but statistically not significant, the higher the dose given higher the soil CEC. K available on soil indicated K available after harvest, after transportation of K nutrients by plants. K available is determined by the amount of fertilizer given, transport of nutrients by plants and soil properties. Similarly, the higher the dose of K fertilizer is given higher the K available in soil. Good fertilizer such as KCl, KNO3 ZK when given into the soil will undergo decomposition into the K⁺ which may be available and absorbed by plants.

Correlation test results showed that a significant correlation was obtained between the cation exchange capacity (CEC) and K available soil after harvest show significant, the higher the dose given higher the soil CEC. K available and 150 kg K fertilizer application dose of 50 kg K2O.ha⁻¹, 100 kg K2O.ha⁻¹ and 150 kg K2O.ha⁻¹ provides enhanced soil CEC but statistically not significant, the higher the dose given higher the soil CEC. K available on soil indicated K available after harvest, after transportation of K nutrients by plants. K available is determined by the amount of fertilizer given, transport of nutrients by plants and soil properties. Similarly, the higher the dose of K fertilizer is given higher the K available in soil. Good fertilizer such as KCl, KNO3 ZK when given into the soil will undergo decomposition into the K⁺ which may be available and absorbed by plants.

**Figure 1.** Effect of kinds of K fertilizer to plant height

Description: Numbers followed by the same letter are not significant with DMRT 5%

Figure 2 shows that with the increase of K fertilizer dose will increase plant height at all dose levels 50 kg K₂O.ha⁻¹, 100 kg K₂O.ha⁻¹ kg and 150 kg K₂O.ha⁻¹. However, the height increase among dose levels were not significant. It can be understood that with the increase of K fertilizer given increase the availability of high-K so that the plant increases.

The plant grows high in relation to the apical dominance due to the interaction between auxin and light [8]. The response of plants to light for a clump of rice depends on the density of which is
reflected in the number of tillers. Auxin as stimulants of endogenous growth (enlargement and elongation of cells) become active (since the lower light intensity), so the plants become taller.

3.4 Yields component

3.4.1 The number of vegetative tillers A wide diversity of K fertilizer effect no significant effect on the number of tillers per cluster during the vegetative phase. K fertilizer doses significantly affect the number of vegetative tillers per cluster. Figure 3 shows that with the addition of K fertilizer 50 kg K₂O.ha⁻¹ increase the total number of tillers from an average of 23 stem per cluster to an average of 24.6 stem per cluster but this increase was not statistically significant. If the dose of K fertilizer increased to 100 kg K₂O.ha⁻¹ total number of tillers per cluster may significantly increase but if the dose of K fertilizer increased again to 150 kg K₂O.ha⁻¹ had lower total tiller number although not significant.

![Figure 3](image-url)

**Figure 3.** Effect kinds of K fertilizer on the number of vegetative tillers maximum total current
Description: Numbers followed by the same letter are not significant with DMRT 5%

3.4.2 The number of productive tillers The number of productive tillers can be seen in Figure 4 and Figure 5. The test results show that a wide diversity and K fertilizers significantly affect the number of productive tillers while the interaction between the two influential not evident.

![Figure 4](image-url)

**Figure 4.** Effect of kinds of K fertilizer on the number of productive tillers per hill
Description: Numbers followed by the same letter are not significant with DMRT 5%

![Figure 5](image-url)

**Figure 5.** Effect of doses of K fertilizer on the number of productive tillers per hill
Description: Numbers followed by the same letter are not significant with DMRT 5%

In Figure 4 shows that the average number of productive tillers highest achieved at ZK fertilizer application and significantly different when compared with KCl and KNO₃ fertilizer. The highest number of productive tillers reached at ZK fertilizer. This is because the sulfate content in the soil is low, then the follow-up of ZK fertilizer can increase the levels of S in the soil. Sulfur or sulfur required in the production of chlorophyll. S is required to produce amino acids (cysteine, methionine and cystin) in plants [13]. In Figure 5 shows that with increasing doses of K fertilizer will increase the
number of productive tillers significantly in a dose of 150 kg K₂O·ha⁻¹. The number of productive tillers as one determinant of productivity of rice is supported by the condition of the reproductive organs (panicle length, number of grains per panicle, length and number of grains per panicle).

3.4.3 Dry grain harvest and dry milled grain The test results show that a wide diversity and K fertilizers significantly affect the weight of dry grain harvest. Results of dry grain harvest is presented in Figure 6 and 7. Based on the figure 6 that the types of fertilizers ZK weight of dry grain harvest produce the highest with an average of 88.104 tons·ha⁻¹ and the lowest KNO₃ fertilizer with the results weight of dry grain harvest average 7.466 tons·ha⁻¹. In figure 7 it can be seen that K fertilizer dose of 100 kg K₂O·ha⁻¹ produced the highest yield that is 8.127 tonnes·ha⁻¹ but when the dose is increased to 150 kg K₂O·ha⁻¹ there was no significant decrease of the yield. This can be explained due to sulfur in the soil are low so that the provision of fertilizer ZK (K₂SO₄) can increase the sulphate in the soil. Sulfate is absorbed by plants can increase chlorophyll of plants as well as nitrogen. Sulfate plays a role in the preparation of proteins, especially cystine, cysteine and methionine. Similarly, an increase in the dose of K fertilizer will increase available K in the soil.

![Figure 6](image1.png)  
**Figure 6.** Effect of kinds of fertilizer K to weight of dry grain harvest  
Description: Numbers followed by the same letter are not significant with DMRT 5%

![Figure 7](image2.png)  
**Figure 7.** Effect of doses of K fertilizer to weight of dry grain harvest  
Description: Numbers followed by the same letter are not significant with DMRT 5%

Production of rice in the form of grain and then into rice after going through several stages of processing. Role sorts K fertilizer to the weight of dry grain harvest and dry milled were not significantly different, while the dose of fertilizer real differences occur only in plants cultivated and nurtured (not controls). K fertilizer increased the weight of dry grain harvest and dry milled. It shows that the character in the form of plant growth is high and the number of seedlings that affect the production (weight of dry grain harvest and dry milled).

The presence of K-available enough in the soil, guaranteeing vigor of the plant. According [14], when potassium is reasonably available in the plant then the plant more resistant to pathogens and stimulate root growth. Better root growth will create more nutrient absorption so that it can be used in the process of metabolism, especially protein synthesis from amino acids and ammonium ions. The result of this synthesis can affect the growth and production of plants. Potassium special effect in the absorption of nutrients, regulation of breathing, transpiration, enzyme and affect the translocation fotosintat. Potassium plays a role in the translocation photosynthates as potassium arrange transportation system, consequently photosynthates can be distributed accordingly so it does not happen at the photosynthesis site where the photosynthates were piling [15].

Functions include potassium, helps maintain osmotic potential and extraction of water, hence the plants are fairly K only a slight loss of water and have a positive influence on stomata closure. Potassium may also serve to balance the charges of anions and affect uptake and transport of the anion. Potassium can help reduce outbreaks of certain diseases and fall, because potassium will
increase the hardness of the plant. This is because K affect the lignin content of tissues sklerenkim [16].

Based on the figure 8 that the highest weight of dry milled grain at ZK fertilizer with an average of 4,408 tons.ha$^{-1}$. With increasing doses of potassium fertilizer up to a dose of 100 kg K$_2$O.ha$^{-1}$ was obtained a yield increase of dry milled grain weight, but when the dose is increased again to 150 kg K$_2$O.ha$^{-1}$ of dry milled grain yield is decreasing as is the case of dry milled grain.

![Figure 8. Effect of kinds of fertilizer K to dry milled grain](image)

**Figure 8.** Effect of kinds of fertilizer K to dry milled grain

Description: Numbers followed by the same letter are not significant with DMRT 5%

3.4.4 The weight of 1000 seeds The test results show that a wide diversity and K fertilizers significantly affect the weight of 1000 seeds. Weight of 1000 seeds results presented in Figure 10 and 11. Weight of 1000 seeds is one indicator of the quality of the crop. Calculation of the weight of 1000 seeds is necessary because it is one of the characteristics listed in the description of a plant variety. According [17], the average weight of 1000 seeds tend to become permanent traits of each plant variety. Use of the weight of 1000 seeds is to find the average weight that can cause constant grain size in some varieties due to the large number of sample, it is able to cover the variations in each individual plant.

![Figure 10. Effect of kinds of K fertilizer to the weight of 1000 seeds](image)

**Figure 10.** Effect of kinds of K fertilizer to the weight of 1000 seeds

Description: Numbers followed by the same letter are not significant with DMRT 5%

One application of heavy use of 1000 seeds is to determine the optimal seed number in a plot of land, knowing the large seeds or weight means signifies the seed when harvested in a state that is really ripe for good seed to be planted or used as seed is a seed which actually matured. In addition, people often choose large seed as a seed for a reason: usually crop of good races, have seeds that are...
bulkier and heavier because of large and heavy seeds is a trait that is inherited, large seeds and the weight is usually sufficiently ripe and the seeds are large and heavy has a lot of food reserves [18].

3.5 Agronomic efficiency
Agronomic efficiency is calculated based on the formula: (kg per hectare results P1 - P0 kg per hectare results) divided kg per hectare of nutrients given = kg / kg nutrient [19]. Agronomic efficiency for weight dry grain harvest is presented in Figure 12. Of the various fertilizers K is given, the higher the dose given to lower the agronomic efficiency of dry grain harvest. Highest agronomic efficiency was achieved by treatment with a dose of fertilizer ZK 50 kg K₂O ha⁻¹ ie 13.60 kg.Kg⁻¹. According [19], that the agronomic value ranges between 10-30, the rate of> 25 indicates that the plant has been getting good farming management system.

![Figure 12. Effect of treatment to the agronomic efficiency](image)
Description: Numbers unfollowed by the letter are not significant with DMRT 5%

4. Conclusion
Various K fertilizer in the form of KCl, ZK, and KNO₃ almost have the same effect on the growth and yield of rice variety IR 64 on Entisols. Dose of K fertilizer increased the growth and yield of rice but an increased dose provides improved meaningful results. Fertilizers K at a dose of 50 kg ha⁻¹ K₂O relatively efficient, with the agronomic efficiency for dry grain highest yield of 13.6 kg / kg K₂O achieved by ZK fertilizer.

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