1874-3315/21

The Open Agriculture Journal

Content list available at: https://openagriculturejournal.com

RESEARCH ARTICLE

Maximizing the Rice Yield (*Oryza Sativa* L.) using NPK Fertilizer

Paiman[1,*], Ardiyanta[1], C. Tri Kusumastuti[1], Sri Gunawan[2] and Fani Ardiani[2]

[1]*Department of Agrotechnology, Faculty of Agriculture, Universitas PGRI Yogyakarta, Yogyakarta, Indonesia*
[2]*Department of Agrotechnology, Faculty of Agriculture, Institut Pertanian STIPER, Yogyakarta, Indonesia*

Abstract:

Background:

Rice has become a primary daily necessity for mostly Indonesian population. The upsurge of national rice production can be done by agricultural intensification through the application of NPK fertilizer.

Objective:

This study aimed to determine the optimum dose of NPK Mutiara fertilizer, which could provide the highest rice yield of Ciherang variety in Alluvial soil.

Methods:

This study was a single factor arranged in a completely randomized design (CRD) with three replications. The NPK Mutiara fertilizer treatment consisted of four doses, *i.e.*, 0, 160, 320, and 480 kg ha^{-1}. The data observations were analyzed by using analysis of variance (ANOVA) at 5% significance levels. The difference between the averages of the treatment was compared using Duncan's new multiple range test (DMRT) at 5% significance levels.

Results:

The results of the research showed that the application of NPK Mutiara fertilizer could increase the growth and yield of the Ciherang variety in Alluvial soil. The quadratic regression analysis revealed that the optimum dose of NPK Mutiata was obtained at 656 kg ha^{-1} with the maximum grains dry weight of 4.26 tons ha^{-1}. The application of NPK Mutiara fertilizer could not affect the shoot root ratio and panicle length.

Conclusion:

The findings of the study suggest that the application of NPK fertilizer interval has not reached the optimum dose in Alluvial soils for the Ciherang variety. Therefore, application of NPK Mutiara fertilizer with doses higher than 480 kg ha^{-1} is required for alluvial soils.

Keywords: Optimum dose, NPK fertilizer, Growth, Yield, Rice, Ciherang variety.

Article History	Received: August 27, 2020	Revised: December 31, 2020	Accepted: January 10, 2021

1. INTRODUCTION

In 2060, the global population is expected to reach 10 billion, and the demand for staple food supplies particularly rice, increases accordingly. On the other side, rice production relies heavily on chemical fertilizers to meet the food demands of the increasing population [1]. Rice is widely consumed as a veritable source of calories [2], and it was consumed by nearly half of the world population. Likewise, In Indonesia, rice is a staple food for most of the Indonesian population. The demand for rice by the Indonesian population continues to grow from year to year [3]. Indonesia's rice import volume in January-November 2018 surged 2.2 million tons compared to January-December 2017, which only reached 305.75 thousand tons [4]. The data illustrates that the national rice production has not been able to meet the needs of the Indonesian population. Considering all of this evidence, it seems that the rice cultivation in Indonesia should be optimized through the use of superior rice varieties.

One of the Indonesian superior rice varieties is Ciherang. It is a new superior variety that is adaptable to the Indonesian environment. Ciherang varieties have advantages over other

---

* Address correspondence to this author at Department of Agrotechnology, Faculty of Agriculture, Universitas PGRI Yogyakarta, Indonesia-55182;
Tel: (+62274) 376038; Fax: (+62274) 376808; E-mail: paiman@upy.ac.id

DOI: 10.2174/1874331502115010033, 2021, *15*, 33-38

varieties. This rice variety has a profitable high yield and a taste that meets the demand of the market. The potential productivity of Ciherang is 6.0 to 8.5 tons ha^{-1} of the dry weight of grain, and crop age is 116 to 125 days after planting (DAP). In addition, this rice crop is resistant to brown planthopper biotype 3, bacterial left blight resistance, and brown planthopper biotype 2 [5]. However, to obtain high yields, this rice variety requires the fulfillment of macro fertilizer such as NPK. Many choices of NPK fertilizers are available in the farmer's environment.

Estimating crop nutrient requirements is essential for informing decisions of optimal nutrient management. However, the nutrient requirements often vary depending on climates and soil conditions [6]. Nitrogen, phosphorus, and potassium are important macronutrients for plant growth and development [1]. The fertilizer as a source of nutrients is a material of production which plays an important role in improving rice productivity. There are many fertilizers on the market. However, farmers prefer NPK Mutiara fertilizer. NPK Mutiara fertilizer is one type of compound fertilizer with at least five elements of macronutrients and micronutrients. The fertilizer is granular in a faded blue color and contains 16% N (nitrogen), 16% P_2O_5 (phosphate), 16% K_2O (potassium), 0.5% MgO (magnesium), and 6% CaO (calcium). Henceforth the fertilizer is called NPK Mutiara (16-16-16) fertilizer. The nutrients element of N, P, and K are macronutrients needed by plants. The N element in the crop functions as a leaf-forming substance (chlorophyll) and protein-forming elements. The P element functions as energy storage and transfer constitute an essential component in nucleic acids, coenzymes, nucleotides, phosphoprotein, phospholipid, and sugar-phosphate. The K element works in starch formation, activating enzymes, and catalyst storage of photosynthesis products [7]. Nitrogen could absorb plants in the form of NO3- and NH4+ ions.

The N element has a vital role for rice crops, *i.e.*, it encourages faster crop growth, improves grain yield and quality by increasing tillers number, leaf area development, grain formation, grain failing, and protein synthesis. Rice plants that are deficient in N have fewer tillers, stunted growth, yellowish-green leaves, and begin to die from the top and then to the middle of the leaf blade. If the N element is excessively given, it will result in detriment, such as weakening straw, causing the crop fall, and decreasing the rice yield quality [8].

The P element function in the crop plays a role in photosynthesis, respiration, transfer and energy storage, cell division and enlargement, and internal operation of other crops. The plant absorbs the big section of the P element in the form of primary orthophosphate ion (H_2PO_4) and the small number in secondary orthophosphate ion (HPO_4^{-2}). The P element is essential in seed formation, helps accelerate root development and germination, improves water efficiency, and increases power resistance to diseases that ultimately enhance the harvest quality. The deficiency of the P element potentially causes maturity delay and reduces seed filling [9]. The P element is a constituent of Adenosine Triphosphate (ATP). The P element directly plays a role in energy storage and transfer and activities involved in crop metabolism. The P element is highly required by rice, especially at the beginning of the growth, because it can support the root formation and additives' number and accelerate flowering and grain maturity [10].

The K element is the third essential nutrient after N and P. Crops absorb the K element in the soil in the form of K^+ ions. This element performs as an activator of many enzymes participating in several crop metabolism processes, including photosynthesis. If the nutrient of K deficiency occurs, it will cause a decrement in photosynthesis and respiratory disorders. This occurrence eventually dampens carbohydrate production. The K element function is essential in protein synthesis, solving carbohydrates, the process of energizing crops, translocation of heavy metals such as Fe, resistance to disease disorders, fruit formation, and it regulates the opening and closing of guards cell in leaf stomata [11]. K element deficiency symptoms are indicated by the burning of leaves from the edges, necrotic patches brown on old leaves and stems.

NPK fertilization has a significant effect on crop height, the tillers number, panicle number per clumps, total grain per panicle, percentage of the empty and filled with grain per panicle, the weight of 1,000 grain, and the potential yield of grain per hectare [12]. The optimum rate of NPK Phonska (15-15-15) fertilizer was 440 kg/ha, as shown with the production performance of 4.12 tons ha^{-1}. The NPK Phonska (15-15-15) fertilizer effectively elevates the growth and grain dry weight, equivalent to standard NPK at the dose of 300-750 kg ha^{-1} [7]. The application dose of 550 kg ha^{-1} NPK Phonska fertilizer gave the highest yield on the total number of grains (174.58 seeds), number of filled grains (144.67 seeds), and grain yield (85.33 g) per rice clump [13].

Rice cultivation can be done in various soil types. Alluvial soil can be utilized, but it needs higher fertilizer input than fertile soil types. According to Bullinger-Weber and Gobat [14], alluvial soil is land plains resulting from the process of deposition and erosion due to flooding so that its characteristics will reflect the composition and properties of the material transported.

Referring to the existing literature, knowledge about NPK fertilizer has significant implications in increasing the growth and yield of rice. Therefore, this study intends to determine the optimum dose of NPK Mutiara fertilizer, which can provide the highest rice yield of Ciherang variety in Alluvial soil.

2. MATERIALS AND METHODS

2.1. Study Area

The study was conducted from February to June 2019. This research was located in a greenhouse facility, Faculty of Agriculture, Universitas PGRI Yogyakarta, Indonesia. The particular territory of Yogyakarta having an elevation of 118 m above means sea levels in the position S 7° 33′ – 8° 12′ and E 110° 00′ – 110° 50′.

2.2. Experiment Design

This study was s single factor and arranged in CRD with three replications. The NPK Mutiara fertilizer treatments consisted of four levels, *i.e.*, 0, 160, 320, and 480 kg ha^{-1}. Each replication consisted of five samples and needed 4 × 3 × 5 = 60 polybags.

2.3. Research Procedures

The soil type used in this research was Alluvial soil. The media planting was made from the soil of 15 kg and cow manure of 1.5 kg or the ratio of 15:1.5. The combination of soil and manure was mixed into one media before putting into a polybag in size of 40 cm × 40 cm. The Ciherang variety was used in this research. The seedlings were done in plastic tubs germination. The seeds of rice were spread on the media surface and covered with a thin soil layer. Watering the media was ensured to keep the field capacity. Two weeks after seeding, the rice seedlings were planted in the soil as deep as 3 cm. Each planting hole was planted with two rice seedlings. Plant spacing between polybag was 25 cm × 25 cm measured from the midpoint polybags, then the plants' number became 160.000 clumps ha^{-1}. The water is filled in the polybags until waterlogging. The urea fertilizer was applied for all treatments as many as 160 kg ha^{-1} in the age of 14 DAP. An addition of NPK Mutiara (16-16-16) fertilizer was applicably suitable for the treatments in the age of 42 DAP. The anticipation of pest attacks of brown planthopper is done by applying Temin pesticides.

2.4. Parameters

The observation was made on the rice growth, including the tillers per clumps, leaf area, shoot dry weight, roots dry weight, stover dry weight, and shoot-root ratio. The rice yield was observed, including panicle length, grain dry weight of grain, and harvest index. Harvest index is the grain dry weight (economic yield) divided by overall crop dry weight (biological yield, including the dry weight of grains).

2.5. Statistical Analysis

The data were analyzed using ANOVA at 5% significance levels [15] with IBM SPSS Statistic 23. The treatment means were compared using DMRT at 5% significance levels.

3. RESULTS

3.1. Component of the Rice Growth

The ANOVA showed that NPK fertilizer was significantly affected on tillers number, leaf area, shoot dry weight, roots dry weight, and stover dry weight, except shoot root ratio. The results of DMRT at a 5% significant level on the component of rice growth are presented in Table **1**.

Table **1** shows that compound NPK fertilizer application could increase rice growth compared to control (treatment of 0 kg ha^{-1} NPK), except for the shoot root ratio. The dose of NPK fertilizer of 480 kg ha^{-1} produced the highest number of tillers, and significantly different from 160 kg ha^{-1} and control, but not significant with 320 kg ha^{-1}. There was a decrease in tillers number in 160 kg ha^{-1} and in 0 kg ha^{-1}. There was no significant difference in the leaf area between the dose of 160, 320, and 480 kg ha^{-1}, but all three treatments were significantly different from the control. The use of NPK fertilizer in the dose of 480 kg ha^{-1} produced the highest root dry weight, and significantly different from 160 and 0 kg ha^{-1}, but not significant with 320 kg ha^{-1}. Table **1** also explains that the highest dry weight of shoots, roots, and stover was achieved in applying NPK fertilizer at a dose of 480 kg ha^{-1}.

Table 1. The effect of NPK on the component of rice growth.

Parameters	Doses of NPK fertilizer (kg ha^{-1})			
		160	320	480
Tillers number (stem clump^{-1})	29,0 C	34,3 bc	42,5 ab	44,7 a
Leaf area (cm^2 Clump^{-1})	825.3 b	1,173.5 a	1,320.2 a	1,405.1 a
Shoot dry weight (g clump^{-1})	10.59 c	13.02 bc	15.33 ab	16.85 a
Root dry weight (g clump^{-1})	3.2 c	4.52 bc	5.35 ab	6.29 a
Shoot root ratio	3,30 a	2,89 a	2,86 a	2,69 a
Stover dry weight (g clump^{-1})	13.8 c	17.55 bc	20.76 ab	22.76 a

Remarks: The numbers tailed by the same characters in the same row are not significantly different at 5% significance levels ($p < 0.005$) based on DMRT.

3.2. Component of the Rice yield

The ANOVA showed that the NPK fertilizer significantly affects the grains dry weight and harvest index, except panicle length. The results of DMRT at a 5% significant level on grain dry weight and harvest index are presented in Table **2**.

Table 2. The effect of NPK fertilizer on the component of rice yield.

Parameters	Doses of NPK fertilizer (kg ha^{-1})			
		160	320	480
Panicle lenght (cm)	20.2 a	20.4 a	21.5 a	21.8 a
Grains dry weight (ton ha^{-1})	1.69 c	2.68 b	3.68 a	4.04 a
Harvest index	0.43 b	0.48 ab	0.53 a	0.53 a

Remarks: The numbers tailed by the same characters in the same row are not significantly different at 5% significance levels ($p < 0.005$) based on DMRT.

The application of NPK fertilizers was able to increase rice yields, except for panicle length. The dose of 320 and 480 kg ha^{-1} produced higher grain dry and significantly different from 160 kg ha^{-1} and control being 0 kg ha^{-1}. The grains' dry weight was lower in the dose of 160 and 0 kg ha^{-1}. The application of more than 480 kg ha^{-1} could also increase the grain dry weight. From the correlation between NPK fertilizer and grain dry weight, the optimum NPK dose can be determined based on quadratic regression. The optimum NPK is obtained from the first derivative of the quadratic regression equation.

The quadratic regression analysis result shows that NPK fertilizer has an effect on grain dry weight, which was obtained as $y = -6\text{E-}06\, x^2 + 0.0079\, x + 1.6635$, and the coefficient of determination (R^2) of 0.99. The first derivative of the quadratic regression obtained the optimum dose of NPK fertilizer of 656 kg ha^{-1} and the grains dry weight of 4.26 tons ha^{-1}. The quadratic regression curve is drawn based on the NPK fertilizer effects on the grains' dry weight (Fig. **1**).

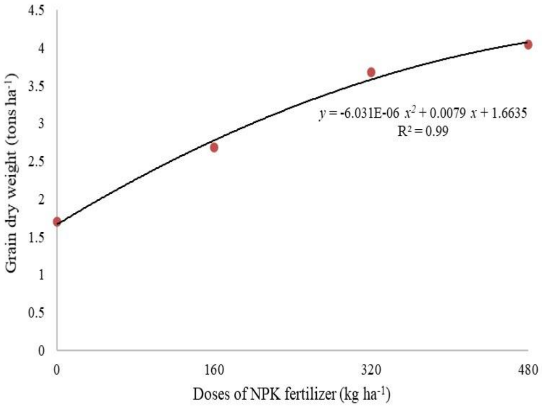

Fig. (1). The effect of NPK fertilizer on the dry weight of grains.

The highest harvest index was obtained from NPK fertilizer at a dose of 480 kg ha^{-1}. It was significant from other treatments, except with a dose of 320 kg ha^{-1}. The harvest index was lower in control. The quadratic regression result showed that NPK fertilizer's effect on harvest index was found to be y = -4.8E-07 x^2 + 0.00043 x + 0.4337, and coefficient of determination (R^2) of 0.99. The first derivative of quadratic regression obtained the optimum dose of NPK at 445.7 kg ha^{-1} and resulted in the harvest index of 0.53. The quadratic regression curve is made from the NPK fertilizer's effect on the harvest index (Fig. **2**).

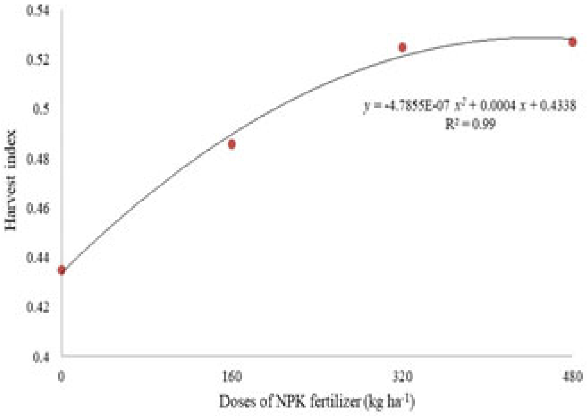

Fig. (2). The effect of NPK fertilizer on harvest index.

4. DISCUSSION

4.1. Components of Rice Growth

It was clearly explained that the dose of 480 kg ha^{-1} NPK Mutiara fertilizer could increase rice growth of the leaf area, tillers' number, shoot dry weight, root dry weight, and strove dry weight, although it is not significantly different from the application of a dose of 320 kg ha^{-1}. The results of this study indicate that NPK fertilizer doses of more than 480 kg ha^{-1} can still increase rice growth. Rice cultivation in Alluvial soils requires the addition of a higher dose of NPK fertilizer due to the low fertility of the soil. The maximum rice growth requires high NPK fertilizer input compared to the previous studies. These findings are in line with Ginting [16]; the highest number of tillers was obtained in the NPK fertilizer 400 kg ha^{-1}.

The application of NPK fertilizer in the soil increases the N content in the soil. N addition frequently stimulates plant growth more than the long-term N effect. Legacy of N tends to be only beneficial for non-N fixing plants in medium-aged soils [17]. N element is needed in large quantities for the shoot and vegetative growth of rice. The N element plays a significant role in forming meristem tissue, stimulates branch, leaf, and shoots. The availability of sufficient N nutrients by applying the proper NPK fertilizer will produce a better crop growth phase. The N element supports the wider leaf growth, then the photosynthesis process [18]. Leaves are the site of photosynthesis and describe the actual production capacity of the crop. Subsequently, carbohydrates could affect the growth, yield, and economic value of the plant. The more full leaves of the plant, followed by increasing chlorophyll content, support the photosynthesis process. The optimum leaf area produces maximum carbohydrates. The N element application sufficiently caused by the increase of shoot growth hence endorses the development of tillers number, stem, and leaf to the maximum. This optimal growth of rice will automatically produce higher shoot dry weight.

NPK fertilizer could accelerate, multiply, strengthen, and extend crop roots so that roots will easily absorb nutrients to the soil. The content of the K element in NPK fertilizer is capable of spurring root development and affecting the absorption of other nutrients. The existence of K and P elements in the soil can control root formation, cleavage, and meristem culture, which maximize the root growth. The P element content plays an important role when forming rice tillers. The P element for the plant functions is as a developmental material of nucleoprotein in every cell core. Thus, it plays a role in forming new cells, including the formatting of prospective rice tillers. The P element is available in the soil which then absorbed by the roots. The P element is part of the cell core. Therefore, it is essential in cell division and development meristem networks to stimulate crop roots growth, especially lateral roots and hair roots, to absorb a higher amount of nutrients. Hence, it results in higher rice tillers. The number of tillers is one of the determining components in rice production per hectare.

4.2. Components of Rice Yield

Based on the results of this study, the application of NPK Mutiara fertilizer can increase the production of dry grain weight per hectare. The application of NPK fertilizer at a dose of 480 kg ha^{-1} can give a yield of 4.04 tons ha^{-1} in Ciherang rice varieties on Alluvial soil. The estimation results show that the highest production of milled dry grain weight is 4.26 tons ha^{-1}, and the optimum dose of NPK fertilizer is 656 kg ha^{-1}. However, the soil type will also determine the production of Ciherang rice varieties. Therefore, a higher dose of NPK fertilizer on marginal soils is highly required. It is proven that the maximum of milled grain dry weight was obtained at 656 kg ha^{-1} and higher than the previous studies. The optimum dosage for the NPK fertilizer is also determined by the soil types where the rice is cultivated. Hartatik's study [7] showed the NPKS optimum dose of 440 kg ha^{-1} produced milled dry grains weight of 4.12 tons ha^{-1} in Inceptisols soil and Shanti's work [19] provided the data that the dose of 300 kg ha^{-1} could produce 6.18 tons ha^{-1} in Ultisols soil. However, those previous studies implemented Inceptisols and Ultisols, which have different characteristics from Alluvial soil. Alluvial soil is marginal soil with lower fertility than Inceptisols and Ultisols soil. Consequently, it requires more doses of NPK fertilizer. The evidence presented thus far supports the idea that the increase of nutrients in Alluvial soil augments the dry weight of grains. In addition, the N, P, and K nutrients also support the soil metabolic process, which eventually affects plant growth.

Plant reproduction and growth are processes that require energy from photosynthetic products [20]. NPK fertilizer can reduce the possibility of flower fall and seed loss due to increasing crop yield. Also, NPK fertilizer can intensify the photosynthesis of crops, therefore it results in higher carbohydrate formation. The P element performs as an element of protein compilers needed for the support of flowers, fruit, and seeds [21]. The P element has the function to accelerate flowering and ripening of grains. The P element is a necessary constituent of Adenosine Diphosphate (ADP). It plays a role in the energy transfer process, and Adenosine Triphosphate (ATP) directly plays a role in the energy storage process. The explanations above confirm the importance of the rice crop's P element, which accelerates flower formation and grain ripening.

In accordance with the present results, some previous studies have demonstrated that the K element plays a role in metabolic processes, namely photosynthesis and respiration in crop growth. The K element regulates the balance of ions in the cell, which sets various metabolic mechanisms like photosynthesis, metabolism carbohydrates, and translocation. Synthetic protein plays a role in the respiration process [22]. The K application promoted early flowering by 1–3 days and regulating flowering in rice production [23]. A higher crop harvest index leads to the increased dry weight of grains of each clump of rice crop. Food reserves (carbohydrate) can be stored in organ crops, namely leaves, stem, and root, in a vegetative phase. In the generative phase, this carbohydrate is transferred to seeds filling (grain). The K element can stimulate carbohydrate translocation from the leaf to the other plant organs especially seed (grain).

By providing optimal NPK, the results of photosynthesis will be directed to fill seeds. The proper application of NPK nutrients can help translocation and storage of carbohydrates so that the harvest index can reach a maximum. The seed filling is needed during the generative phase. Therefore, it requires the storage of carbohydrate from photosynthesis during the production phase. The seed filling period requires higher carbohydrate that occurs at the maximum process of photosynthesis. The NPK fertilizer influences the number of carbohydrates stored by the crop (stored capacity).

This section has attempted to provide a brief summary of the literature and the present study relating to the application of NPK Mutiara fertilizer in rice cultivation. Different doses of NPK have been proposed to provide solutions for increasing rice production. The present study was designed to determine the optimum dose of NPK Mutiara fertilizer on Ciherang rice variety.

CONCLUSION

Based on the research results and the discussion above, the conclusion derived from this study is that the application of NPK Mutiara fertilizer in Alluvial soil could increase the growth and yield of the Ciherang rice. In this study, higher grain dry weight results were achieved at an NPK Mutiara fertilizer dose of 480 kg ha^{-1}. In this study, the use of optimum NPK fertilizer has not been found, so the next research needs to use a higher dose treatment, especially rice cultivation in alluvial soils.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No humans or animals were used in this research.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

FUNDING

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Declared none.

REFERENCES

[1] Kaushik S, Djiwanti SR. Genetic improvements of traits for enhancing NPK acquisition and utilization efficiency in plants.Plant Macronutrient Use Efficiency. Elsevier Inc. 2017; pp. 267-83. [http://dx.doi.org/10.1016/B978-0-12-811308-0.00015-6]

[2] Djaman K, Rudnick DR, Moukoumbi YD, Sow A, Irmak S. Actual evapotranspiration and crop coefficients of irrigated lowland rice (*Oryza sativa* L.) under semiarid climate. Ital J Agron 2019; 14(1): 19-25. [http://dx.doi.org/10.4081/ija.2019.1059]

[3] Anonymous . Ringkasan eksekutif luas panen dan produksi beras di Indonesia 2018. Jakarta: Badan Pusat Statistik 2018. [https://www.bps.go.id/publication/2018/12/21/7faa198f77150c12c31df395/ringkasan-eksekutif-luas-panen-dan-produksi-beras-di-indonesia-2018.html] (in Indonesian)

[4] Anonymous . Berapa impor beras 2018?. Jakarta: Badan Pusat Statistik 2019. [https://databoks.katadata.co.id/datapublish/2019/01/24/berapa-impor-beras-2018] (in Indonesian)

[5] Anonymous . Ciherang variety. Jakarta: Balai Besar Pelatihan

Tanaman Padi, Balitbangtan, Kementerian Pertanian 2020. [http://bbpadi.litbang.pertanian.go.id/index.php/varietas-padi/inbrida-padi-sawah-inpari/ciherang] (in Indonesian)

[6] Yin Y, Ying H, Zheng H, Zhang Q, Xue Y, Cui Z. Estimation of NPK requirements for rice production in diverse Chinese environments under optimal fertilization rates. Agric For Meteorol 2019; 279: 1-6. [http://dx.doi.org/10.1016/j.agrformet.2019.107756]

[7] Hartatik W, Widowati LR. Effect of compound fertilizer NPKS and NPK on rice growth and yield on Inceptisol. Penelitian Pertanian Tanaman Pangan 2015; 34(3): 175-86. [http://dx.doi.org/10.21082/jpptp.v34n3.2015.p175-185]

[8] Kaya E. Pengaruh pupuk organik dan pupuk NPK terhadap pH dan K-tersedia tanah serta serapan-K, pertumbuhan dan hasil padi sawah (*Oriza sativa* L.). Buana Sains 2014; 14(2): 113-22.

[9] 2014.https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwi0nImsubfrAhW573MBHXKmBB4QFjAAegQIARAB&url=http%3A%2F%2Fwww.bppjambi.info%2Fdwnfilemanager.asp%3Fid%3D1329&usg=AOvVaw0p8YjlcRWlFCUX9bng7U21

[10] Abdulrachman S, Sembiring H. Penentuan takaran pupuk fosfat untuk tanaman padi sawah. Iptek Tanaman Pangan 2006; 1: 79-87. [in Indonesian].

[11] Firmansyah I, Syakir M. The influence of dose combination fertilizer N, P, and K. J. Hort 2017; 27(1): 69-78. [http://dx.doi.org/10.21082/jhort.v27n1.2017.p69-78]

[12] Samira D, Gani A, Mcleod M. Effect of NPK fertilizer and biochar residue on paddy growth and yield of second planting

[13] Yafizham, Lukiwati DR. Produksi empat varietas padi sawah yang diberi kombinasi pupuk Bio-Slurry dan NPK. Agrotech Res J 2019; 3(1): 23-7. [http://dx.doi.org/10.20961/agrotechresj.v3i1.30012]

[14] Bullinger-Weber G, Gobat JM. Identification of facies models in alluvial soil formation: The case of a Swiss alpine floodplain. Geomorphology 2006; 74: 181-95. [http://dx.doi.org/10.1016/j.geomorph.2005.07.016]

[15] Sime HD, Mbong GA, Malla DK, Suh C. Effect of different doses of NPK fertilizer on the infection coefficient of rice (*Oryza sativa* L.) blast in Ndop, North West of Cameron. Agronomie Africaine 2017; 29(3): 245-55.

[16] Ginting J. Meiriani, Sitepu F, Sipayung R, Ramadhan IA. Increased growth and production of irrigated rice by providing cow organic manure and NPK compound fertilizers with planting systems Jajar Legowo 4:1 in the Village of Tanjung Keriahan, Langkat Regency North Sumatera In International Conference on Agriculture, Environment and Food Security (AEFS). 1-6.

[17] Sun D, Ardestani MM, Frouz J. Nitrogen fertilization, and it’s legacy has inconsistent and often negative effects on plant growth in undeveloped post-mining soils. Soil Tillage Res 2019; 195: 1-9. [http://dx.doi.org/10.1016/j.still.2019.104380]

[18] Sibuarian IS, Suntari R, Prijono S. Pengaruh aplikasi urea dan pupuk organik cair (urin sapi dan teh kompos sampah) terhadap serapann serta produksi sawi pada entisol. Jurnal Tanah Dan Sumberdaya Lahan 2016; 3(1): 303-10.

[19] Shanti S, Nirmala R. Application of NPK Phonska fertilizer and plant growth hormone (Ratu Biogen) to the growth and yield of paddy rice (*Oryza sativa* L.) on Ultisols. J Agroteknologi Trop Lembab 2020; 3(1): 19-26.

[20] Chen G, Zhang Y, Ruan B, *et al.* OsHAK1 controls the vegetative growth and panicle fertility of rice by its effect on potassium-mediated sugar metabolism. Plant Sci 2018; 274: 261-70. [http://dx.doi.org/10.1016/j.plantsci.2018.05.034] [PMID: 30080612]

[21] Zain NAM, Ismail MR. Effects of potassium rates and types on growth, leaf gas exchange, and biochemical changes in rice (*Oryza sativa* L.) planted under cyclic water stress. Agric Water Manage 2015; 164: 83-90. [http://dx.doi.org/10.1016/j.agwat.2015.09.022]

[22] Lan ZM, Lin XJ, Wang F, Zhang H, Chen CR. Phosphorus availability and rice grain yield in paddy soil in response to long-term fertilization. Biol Fertil Soils 2012; 48: 579-88. [http://dx.doi.org/10.1007/s00374-011-0650-5]

[23] Ye T, Li Y, Zhang J, *et al.* Nitrogen, phosphorus, and potassium fertilization affects the flowering time of rice (*Oryza sativa* L.). Glob Ecol Conserv 2019; 20: 1-9. [http://dx.doi.org/10.1016/j.gecco.2019.e00753]
