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The Influence of Phosphate Fertilizer and Plant Growth Regulators on the Growth and Yield of Ratoon Rice (*Oryza sativa* L.) Grown on Swampland

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ABSTRACT

This research aimed to study the influence of phosphate fertilizer and plant growth regulator applications on the growth and yield of ratoon rice grown on swampland. The research was conducted in September 2016 to January 2017 at the greenhouse of Department of Soil Science, Faculty of Agriculture, Sriwijaya University. Soil characteristics were analyzed in the Laboratory of Chemistry, Biology and Soil Fertility, Department of Soil Science, Faculty of Agriculture, Sriwijaya University. The experiment was arranged in a factorial Completely Randomized Design. The first factor was the phospate fertilizer dosages, *i.e.* 150 kg ha^{-1} (P1), 200 kg ha^{-1} (P2), 250 kg ha^{-1} (P3). The second factor was the plant growth regulator treatments, consisting of control (Z0), Cytokinin 20 ppm (Z1), Gibberellin 60 ppm (Z3). The results showed that the application of P fertilizer did not affect the yield and growth of ratoon rice. However, the application of Plant Growth Regulators resulted in a significant effect on the growth and yield of ratoon rice. The application of Plant Growth Regulator of Gibberellin with the dosage of 60 ppm was able to increase the percentage of filled grains (84.93%), decrease the percentage of empty grains (15.07%), increase the weight of 100 grains (3.63 g) and increase the dry weight of milled grains (7.80 Mg ha^{-1}). It is suggested that the treatment resulted in better plant growth and yield obtained in the current study might be recommended for ratoon cultivation in swampland.

Keywords: Cytokinin, gibberellin, rice, phosphorus, yield, ratoon, swampland

ABSTRAK

Penelitian ini bertujuan untuk mengetahui pengaruh aplikasi pupuk fosfat dan pemberian zat pengatur tumbuh terhadap pertumbuhan dan produksi padi ratun pada tanah rawa lebak. Penelitian ini dilaksanakan sejak September 2016 sampai Januari 2017 di rumah kaca Jurusan Ilmu Tanah, Fakultas Pertanian, Universitas Sriwijaya dan analisis sifat tanah dilaksanakan di Laboratorium Ilmu tanah, Fakultas Pertanian, Universitas Sriwijaya. Penelitian dirancang menggunakan Rancangan Faktorial Acak Lengkap. Faktor pertama adalah dosis pupuk fosfat, yaitu 150 kg ha^{-1} (P1), 200 kg ha^{-1} (P2), 250 kg ha^{-1} (P3). Faktor kedua adalah perlakuan zat pengatur tumbuh, yaitu kontrol (Z0), sitokinin 20 ppm (Z1), Giberelin 60 ppm (Z3). Hasil penelitian menunjukkan bahwa aplikasi pupuk P tidak mempengaruhi pertumbuhan dan produksi padi ratun. Tetapi perlakuan zat pengatur tumbuh mempunyai pengaruh yang nyata terhadap pertumbuhan dan produksi padi ratun. Aplikasi zat pengatur tumbuh giberelin dengan dosis 60 ppm mampu meningkatkan persentase gabah isi (84,93 %), menurunkan persentase gabah hampa (15,07%), meningkatkan berat 100 butir padi (3,63 g) dan meningkatkan berat gabah kering giling (7,8 Mg ha^{-1}). Disarankan perlakuan terbaik dalam penelitian ini direkomendasikan untuk diaplikasikan pada budidaya padi ratun pada lahan rawa lebak.

Kata Kunci: Fosfor, giberelin, lahan rawa, padi, produksi, ratun, sitokinin

INTRODUCTION

Indonesia is known as an agricultural producing country with a wide range of soil types and fertility. Due to rapid development of industrial and housing area, many fertile agricultural soils have been lost. This leads to an alternatif to use of marginal swampland for the extention of agricultural area. Swampland spreads all over in Indonesia and there are about 2.0 millions ha of swampland in South Sumatra, which are potential for rice cultivation (Waluyo et al. 2006).

Swampland generally contains relatively low available phosphorus due to soil acidity that causes phosphorus bound to Fe- and Al-(hydr)oxides, resulting in less soluble and unavailable P to plants. In addition, the study by Fitri *et al.* (2014) indicated that the P content in swampland was very low (7.50 ppm), which further caused a high number of empty grains of rice. The percentage of empty rice grains of the main crop were 7.34% - 30.90%, whereas the empty rice grains of ratoon crop were 0.22% - 18%. High number of empty rice grains can decrease rice yield, so that efforts should be made by applying phosphorus fertilizer to the soil. Application of appropriate fertilization technology can be an option to increase nutrient content in soils and increase soil pH. The accuracy of fertilization is crucial for the growth and productivity of plants. Fertilization should be done effectively and efficiently, in accordance to the Five Right principles, *i.e.* right time, right dose, right method, right source and right place (Arifin *et al.* 2006).

An effort in optimizing rice cultivation in swampland can be done by applying main rice cultivation followed by ratoon rice cultivation. Ratoon rice grows after the main rice is harvested. Benefits of ratoon cropping system are: 1) increase rice productivity per planting season, 2) production cost is cheaper because this system does not require soil tillage and seedlings and 3) the required amount of fertilizer will be less. Some of the superior varieties can produce yield of ratoon rice 40% up to 60% of the main crop (Susilawati 2013).

Yield of ratoon rice is in general lower compared to yield of main crop. Better cultivation and management techniques may increase the yield of ratoon crops, such as the application of plant growth regulator (PGR) on rice plants. Cytokinin and gibberellin are two types of PGR that can stimulate plant growth. Generally, the active growth regulator affects plants in very little doses (Wahyurini 2009).

Some growth regulators, such as cytokinin and gibberellin, have been used in research and showed some effects on plant growth. However, the number of study on the use of plant growth regulators for rice plants grown on swampland is still relatively small and has not been published widely. Therefore, it is necessary to study the effects of PGR and phosphate fertilizer applications on rice yield in swampland. It is expected that the results of this study can be used for management of rice grown on swampland.

The objectives of this research are to study the effects of P fertilizer and PGR applications on the yield of ratoon rice grown on swampland, and to find out the appropriate dose of P fertilizer and the good effects of the combination of the two treatments on the yield of ratoon rice.

The results of this research is expected to add novel information on the strategy and appropriate technology in optimizing rice cultivation in swamp land. In addition, it is also expected to assist farmers in terms of increasing the yield of rice, improving P fertilization efficiency, increasing the intensity of rice cultivation through ratoon cropping system, as well as studying the use of some PGR in increasing the yield of ratoon rice.

MATERIALS AND METHODS

Study Site

This research was conducted in the greenhouse of Department of Soil Science, Faculty of Agriculture, Sriwijaya University, Indralaya Campus, South Sumatera. This research was carried out from September 2016 to January 2017. Soil and crop analyses were carried out in the Laboratory of Soil Chemistry and Soil Fertility, Department of Soil Science, Faculty of Agriculture, Sriwijaya University.

Materials Used in the Study

Soil samples were taken from swampland around Faculty of Agriculture, Sriwijaya University, Indralaya Campus, South Sumatra. The soil samples were air dried and sieved using 2 mm sieving and put into each pot about 9 kg. Three seeds were planted in each pot. After the main rice was harvested, the clumps were cut about 20 cm high and the tillers were grown for ratoon. This research used Ciherang rice variety, plant growth regulators of Gibberellin and Cytokinin, and fertilizers of Urea, KCl and SP-36.

Experimental Design and Data Analysis

The experiment was arranged in a factorial Completely Randomized Design with 3 replications. The first factor was the dosage of SP-36 (P fertilizer) that consisted of three levels, *i.e.* 1) P1: 150 kg

Table 1. Characteristics of soil used in the experiment.

Soil Properties	Unit	Value	Criteria*
pH (H_2O) 1:1	-	3.62	Very acid
pH (KCl) 1:1	-	2.83	Very acid
Organic-C	%	6.94	Very high
Total-N	%	0.28	Medium
Available-P	ppm	7.50	Low
Exchangable-K	me $100g^{-1}$	0.19	Low
Exchangable-Na	me $100g^{-1}$	0.11	Low
Exchangable-Ca	me $100g^{-1}$	0.28	Very low
Exchangable-Mg	me $100g^{-1}$	0.22	Very low
CEC	me $100g^{-1}$	13.05	Low
Exchangable-Al	me $100g^{-1}$	2.16	High
Exchangable-H	me $100g^{-1}$	0.28	Low
Texture class: Sandy loam			
Sand	%	73.54	
Silt	%	18.38	
Clay	%	8.08	

Note: *The criteria proposed by Balai Penelitian Tanah (2005).

ha^{-1}, 2) P2: 200 kg ha^{-1}, 3) P3: 250 kg ha^{-1}. The second factor was the PGR treatment that consisted of three levels: 1) Z0: without PGR, 2) Z1: Cytokinin (BAP) at a dose of 20 ppm, 3) Z2: Gibberellin (GA3) at a dose of 60 ppm.

There were 3 × 3 × 3 treatments with 5 series, so in total there were 135 pots. If the results of analysis of variance indicated the significant difference between the treatments, then the Honest Significant Difference (HSD) test was done at 5% significance level.

The variables measured were as follow: soil characteristics, plant height measured weekly, the number of tiller per clump, the number of productive tiller, weight of 100 grains, percentage of empty and filled grains, and dry weight of milled grains.

RESULTS AND DISCUSSION

Soil Characteristics

The results of soil analysis in Table 1 indicated that the soil used in this study has low fertility level. The soil characteristics are presented in Table 1. This soil is considered as an acid sulphate soil because it contains pyrite at < 80 cm depth. Therefore, the pH of this soil is very acid and the nutrient contents are in the level of very low to moderate.

The Effect of P Fertilization and Plant Growth Regulator Application on Plant Height

The results of analysis of variance indicated that the application of P fertilizer did not significantly affect the height of ratoon rice, but PGR application showed a significant effect. There was no significant interaction effect between P fertilization and PGR application on the height of rice plants.

The highest plant height was measured in the plots applied with PGR of gibberellin with the average of 74.13 cm, while the average height of the plants without application of PGR (control) was 43.78 cm. The effect of gibberellin application on the height of ratoon plants is more significant compared to the application of cytokinin and control. It showed that the application of gibberellin at a dose of 60 ppm resulted in the highest height of ratoon rice (Figure 1 and 2).

The Effects of P Fertilization and Plant Growth Regulator Application on the Maximum Number of Tiller and the Number of Productive Tiller

The analysis of variance indicated that the application of P fertilizer has no significant effect on the maximum number of tiller and the number of productive tiller of ratoon plants, but the application of PGR has a significant effect only on the maximum number of tiller. There was no interaction effect between P fertilization and PGR application on the maximum number of tiller and the number of productive tiller of rice.

Phosphate fertilization did not affect the maximum number of tiller, while PGR application significantly influenced the maximum number of tiller at 6 weeks of plant growth. The application of gibberel-

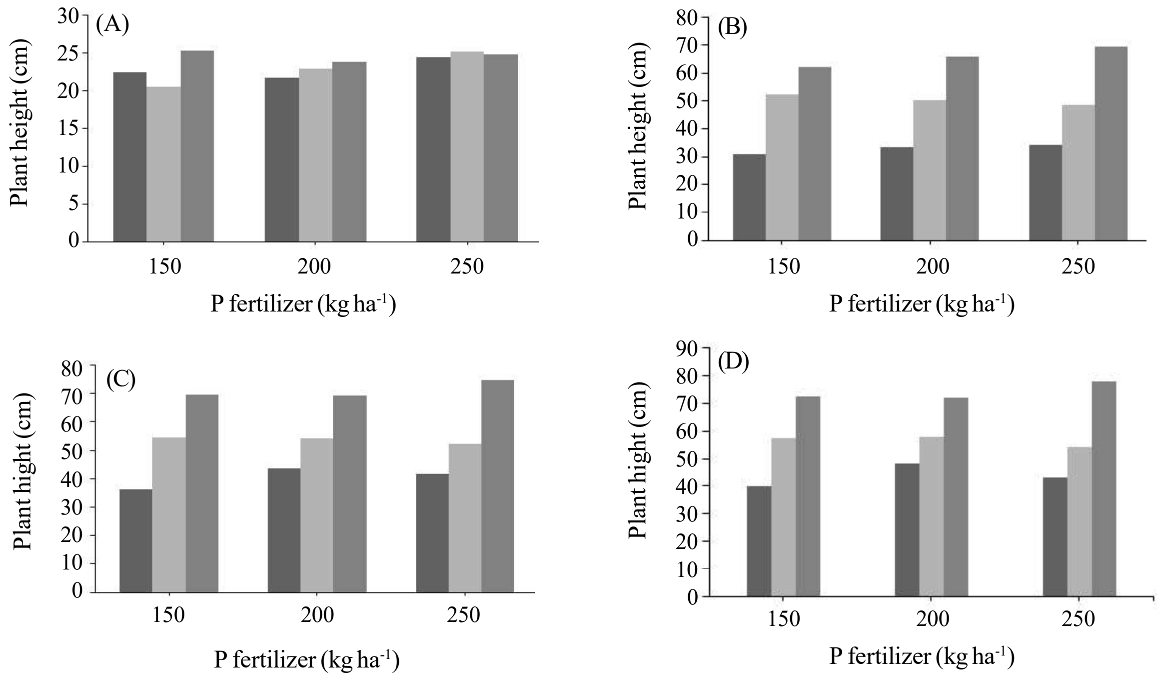

Figure 1. The effects of P fertilization and PGR application on plant height at 2nd week (A), 4th week (B), 6th week (C), 8th week (D) of ratoon rice. : control; : cytokinin; : gibberellin

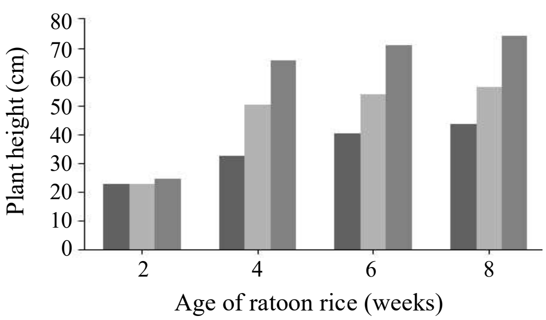

Figure 2. The effects of PGR application on plant height. : control; : cytokinin; : gibberellin

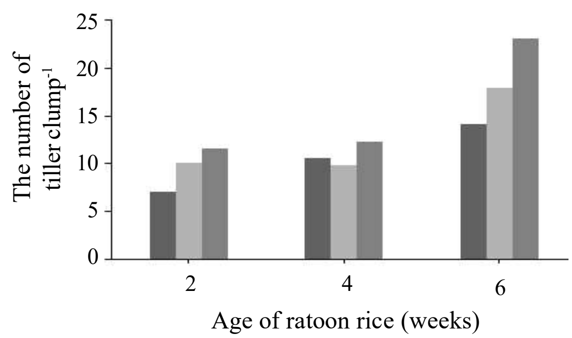

Figure 3. The effects of PGR application on the number of tiller clump^{-1}. : control; : cytokinin; : gibberellin

lin resulted in the highest number of tiller, *i.e.* 23.17, while the plants without PGR application (control) resulted in the lowest number of tiller, *i.e.* 14.20. The application of gibberellin showed more significant effect on the maximum number of tiller of ratoon rice compared to the application of cytokinin and control. The results of HSD test at 5% level showed that the application of gibberellin with a dose of 60 ppm resulted in the highest number of tiller of ratoon rice (Figure 3).

The Effects of P Fertilization and PGR Application on 100 Grain Weight, Percentage of Filled Grains and Empty Grains of Ratoon Rice

The results of analysis of variance indicated that the application of P fertilizer and PGR did not significantly affect the weight of 100 rice grains and the percentage of filled rice grains. However, the PGR application resulted in a significant effect on the percentage of empty rice grains. There was no

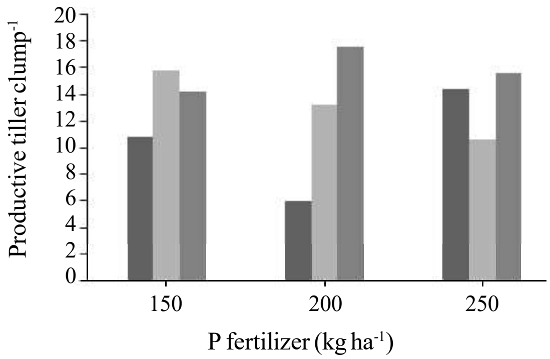

Figure 4. The effects of P fertilization and PGR application on the number of productive tiller clump^{-1}. ■: control; ■: cytokinin; ■: gibberellin

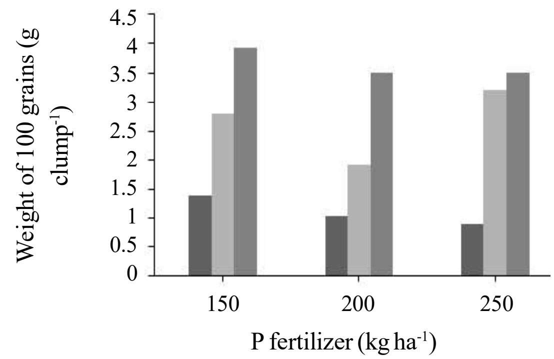

Figure 5. The effects of P fertilization and PGR application on the weight of 100 grains clump^{-1}. ■: control; ■: cytokinin; ■: gibberellin

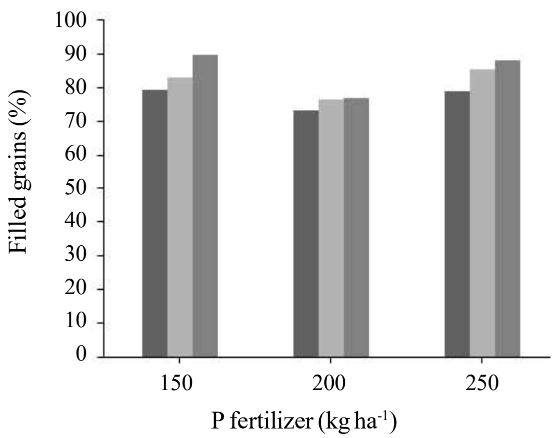

Figure 6. The effects of P fertilization and PGR application on percentage of filled grains. ■: control; ■: cytokinin; ■: gibberellin

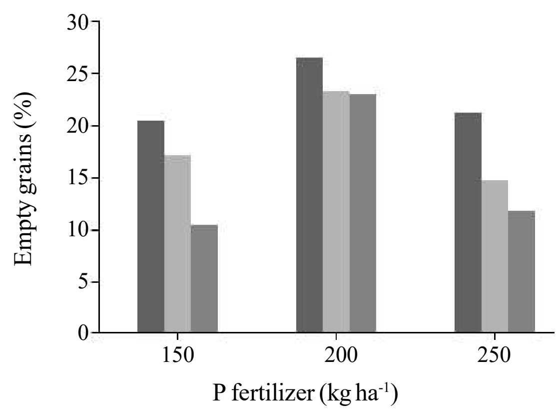

Figure 7. The effects of P fertilization and PGR application on percentage of empty grains. ■: control; ■: cytokinin; ■: gibberellin

significant interaction effect between P fertilization and PGR application on the weight of 100 grains, percentage of filled grains and percentage of empty grains. The average weight of 100 grains, percentage of filled grains and empty grains of rice are presented in Figure 5, 6, 7 and 8.

The application of gibberellin resulted in the lowest percentage of empty grains, *i.e.* 15.07%, while

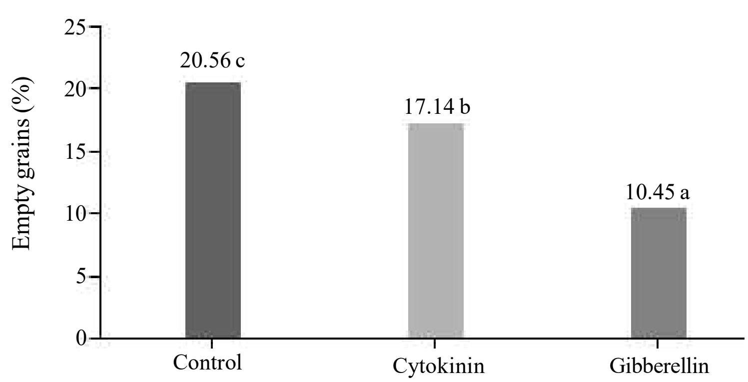

Figure 8. The effects of PGR application on percentage of empty grains.

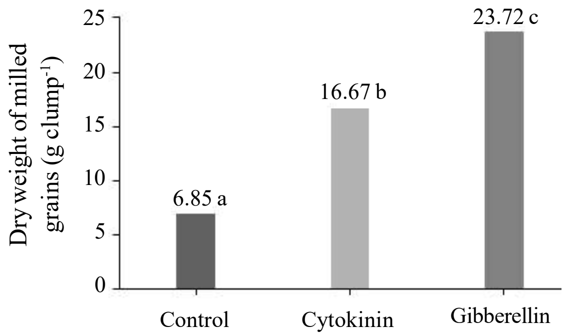

Figure 9. The effect of PGR application on dry weight of milled grains in g clump^{-1}.

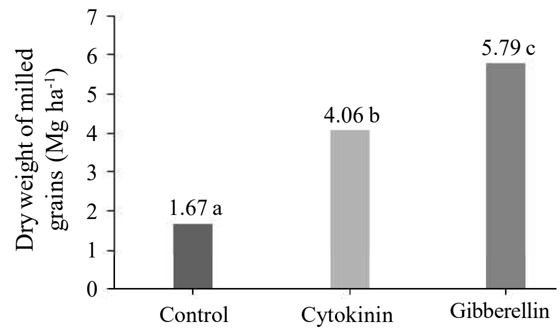

Figure 10. The effect of PGR application on dry weight of milled grains in Mg ha^{-1}.

the plant without PGR application (control) had the the highest percentage of empty grains, *i.e.* 22.79%. The result showed that the application of gibberellin on rice plants can decrease the number of empty grains.

The Effects of P fertilization and PGR Application on Dry Weight of Milled Grains

The results of analysis of variance indicated that the application of P fertilizer did not affect the dry weight of milled grains of ratoon rice. However, the PGR application showed a significant effect on the dry weight of milled grains. There was no interaction effect between P fertilization and PGR application on the dry weight of milled grains. The dry weight of milled grains of ratoon rice is presented in Figure 9 and 10.

The results showed that P fertilization showed no significant effect on the dry weight of milled grains of ratoon rice. However, PGR application significantly affected the dry weight of milled grains. The application of gibberellin resulted in the highest dry weight of milled grains, *i.e.* 23.72 g clump^{-1} or 5.79 Mg ha^{-1}. The rice plants without PGR application (control) resulted in the lowest dry weight of milled grains of ratoon rice, *i.e.* 6.85 g clump^{-1} or 1.67 Mg ha^{-1}.

Discussion

The results of soil analysis showed that the soil samples from the swampland has a very acid pH (3.62). The low soil pH makes plants difficult to absorb N, P and K elements, causing slow growth rate and low yield of plants. Organic-C content in the soil is very high (6.94%). The organic-C content of the soil was an indicator of the accumulation of organic matter in the soil. The total-N content is moderate (0.28%) and the amount of available-P is high (27.60 ppm). The amount of exchangeable-K is low (0.19 cmol kg^{-1}), exchangeable-Na is low (0.11 cmol kg^{-1}), exchangeable-Ca is very low (0.28 cmol kg^{-1}), and exchangeable-Mg is very low (0.22 cmol kg^{-1}).

Cation Exchange Capacity (CEC) of the soil is low (13.05 me 100 g^{-1}). The low CEC of the soil is probably due to the high percentage of sand fraction (73.54%) and very low clay fraction (8.08%). Cation Exchange Capacity of the soil affects soil fertility, the higher the soil CEC, the more fertile the soil and its ability to absorb fertilizer and vice versa. Exchangeable-Al and -H levels of the soil are 2.16 me 100 g^{-1} (very high) and 0.28 me 100 g^{-1} (low), respectively. Aluminium is commonly found in acid soil with pH below 5 and in the soil that contains acid sulphate layer, like the soil used in the current experiment. Herviyanti *et al.* (2010) indicated that in submerged condition, stable Fe^{3+} would change into soluble Fe^{2+} in which the excess amount of this cation form would harm plant growth.

Application of PGR resulted in a significant effect on the plant height, percentage of empty grains, maximum number of tiller at week 6 and yield. The application of gibberellin resulted in the highest increase of plant growth and yield of ratoon rice. This is due to gibberellin can increase the cell wall turgor that resulted in cell wall stretching, and can push the wall and membrane cells to grow larger. Utama (2015) reported that the application of gibberellin affects plant height, in which the exogenous gibberellin would increase the amount of indigenous gibberellin that already exist in plant, also would increase the number and size of cells, affecting vegetative growth of plant such as plant height and reducing the risk of plant dwarf.

The application of fertilizer or PGR did not show a significant effect on the number of productive tiller, and there was no significant interaction effect between P fertilization and PGR application on the number of productive tiller of ratoon crop. Although the number of productive tiller was not affected by P fertilization and PGR application, the number of productive tiller was rather high (14 -22 tillers clump^{-1}). Tarjat *et al.* (2000) indicated that the number of productive tiller of Ciherang rice variety is 14-17 tillers clump^{-1}. The number of productive tiller resulted in this study is also higher than the number of productive tiller reported in the study of Herdyanti *et al.* (2015), in which Ciherang ratoon rice produced 20.8 tillers clump^{-1}.

Gibberellin is a growth regulator that significantly affects the number of productive tiller on ratoon crop. The type of gibberellin applied to the plants was GA3 or Gibberellin Acid. Gibberellin actively exhibits many physiological effects, depending on the type of gibberellin and plant species. Some of the physiological effects include the increased number and size of cells, so the gibberellin could accelerate the growth of plants, including the formation of new tillers and increasing the size of panicles (Annisah 2009)

Gibberellin also affects the generative growth of plants. According to study of Annisah (2009), the addition of gibberellin resulted in a very significant effect on the vegetative growth of plant and this effect continued in the generative phase. In the generative phase, gibberellin hormone would increase the storage capacity of photosynthates, resulting in enlargement of the storage tissue. As a result, the plants are able to receive more photosynthates and produce larger storage organs such as rice grains.

Phosphorus fertilization did not show a significant effect on the weight of 100 grains. However, the average weight of 100 grains in this study was 3.63 g clump^{-1}, which exceeded the average weight of 100 grains of Ciherang varieties in general (2.8 g clump^{-1}) (Trajat 2000). The study by Faruq *et al.* 2014 indicated that the weight of 100 grains of ratoon rice was about 0.7 to 1.9 g clump^{-1}.

The highest yield of dried milled grains was found in the treatment of gibberellin, *i.e.* 5.79 Mg ha^{-1}. This result is rather similar to the finding by Herdyanti *et al.* 2015 in which the yield of ratoon rice applied with 50% (NPK) and rice straw was 6.7 Mg ha^{-1}. According to study of Alizadeh and Habibi (2016) the yield of ratoon rice crop was about 65.97%. Compared to the yield of main crop of Ciherang variety (about 6 to 8.5 Mg ha^{-1}), the yield in the current study was rather high, *i.e.* more than 65%.

Phosphorus fertilization did not show a significant effect on the growth and yield of ratoon crop, which could be caused by very low pH (Table 1) and high amount of exchangeable-Al of the soil. This condition leads to P fixation by Al and the P is not available for plant uptake. Therefore, the application of lime and higher dose of P were needed to overcome this problem. It seems that PGR application especially gibberellin could increase plant growth and yield of ratoon rice, eventhough P was not available at optimum level for the plants. The results indicated that the application of gibberellin is very important for ratoon crop, because there is no fertilizer application for ratoon crop and ratoon crop depends on the amount of residual fertilizers from previous main crop.

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CONCLUSIONS

The application of P fertilizer with various doses did not show a significant effect on the growth and yield of ratoon rice.

The application of gibberellin as one type of growth regulator resulted in the increase of yield and growth of rice plants grown on swampland soil with the yield of 5.79 Mg ha^{-1}, plant height of 74.13 cm and the maximum number of tiller of 23.17 clump^{-1}.

There was no significant interaction effect between P fertilization and the application of growth regulator on the growth and yield of ratoon rice.

It is suggested to apply gibberellin in ratoon cultivation to obtain an optimum rice yield.

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