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Application of potassium fertilizer and plant growth regulators to the growth and productivity of purple sweet potato

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ABSTRACT

The study aimed to determine the effect of plant growth regulators and potassium fertilizer on the growth and productivity of three clones of purple sweet potato. The experiment was conducted at IPB University experimental station in Leuwikopo Dramaga Bogor for seven months. The study used a split-plot design with three factors and three replications. The first factor was as a subplot, namely plant growth regulators (PGR) application which consisted of two levels of without PGR (S0) and with PGR (S1) concentration of 2 cc l^{-1} of water (2,000 ppm). The second factor was as a subplot, namely rates of potassium chloride fertilizer (60, 120, 180 kg ha^{-1} K_2O). The third factor as the main plot was sweet potato clones of (K1) Ayamurasaki, (K2) RIS-03063-05, and (K3) MSU 03028-10. The concentration of 2,000 ppm PGR did not significantly affect growth and tuber yield components. Potassium chloride K_2O of 60 kg ha^{-1} up to 180 kg ha^{-1} did not significantly affect growth and tuber yield components. MSU 03028-10 clone had the highest total tuber yield (1537.8), healthy tuber (1529.9), unmarketable tuber (740.3), and small tuber (709.0). MSU 03028-10 clones have the longest stem length and the largest number of leaves 3-12 WAP. This study indicates that the MSU 03028-10 clone produces better growth and productivity than other clones.

ABSTRAK

Penelitian bertujuan untuk mengetahui pengaruh zat pengatur tumbuh dan pupuk kalium terhadap pertumbuhan dan produktivitas tiga klon ubi jalar ungu. Percobaan dilakukan di Kebun Percobaan IPB University di Leuwikopo Dramaga Bogor selama tujuh bulan. Penelitian menggunakan rancangan petak terbagi (*split-plot design*) dengan tiga faktor dan tiga ulangan. Faktor pertama sebagai anak petak yaitu pemberian zat pengatur tumbuh (PGR) yang terdiri dari dua taraf yaitu tanpa PGR (S0) dan dengan PGR (S1) konsentrasi 2 cc l^{-1} air (2.000 ppm). Faktor kedua sebagai anak petak yaitu takaran pupuk kalium klorida (60, 120, 180 kg ha^{-1} K_2O). Faktor ketiga sebagai petak utama adalah klon ubi jalar (K1) Ayamurasaki, (K2) RIS-03063-05, dan (K3) MSU 03028-10. Konsentrasi PGR 2.000 ppm tidak berpengaruh nyata terhadap komponen pertumbuhan dan hasil umbi. Kalium klorida K_2O ukuran 60 kg ha^{-1} sampai dengan 180 kg ha^{-1} tidak berpengaruh nyata terhadap komponen pertumbuhan dan hasil umbi. Klon MSU 03028-10 mempunyai hasil total umbi tertinggi (1537,8), umbi sehat (1529,9), umbi tidak layak jual (740,3), dan umbi kecil (709,0). Klon MSU 03028-10 mempunyai panjang batang terpanjang dan jumlah daun terbanyak 3-12 MST. Penelitian ini menunjukkan bahwa klon MSU 03028-10 menghasilkan pertumbuhan dan produktivitas yang lebih baik dibandingkan klon lainnya.

Keywords: *clone, sweet potato, vegetative*

INTRODUCTION

Indonesia has local sweet potato resources in several parts of Indonesia as a source of biodiversity. In Indonesia, sweet potatoes have spread almost to various parts of Indonesia. Some of Indonesia's local sweet potatoes include Cilembu sweet potatoes from the Cilembu region of West Java, Goroho sweet potatoes from the Gorontalo area, Jeneponto sweet potatoes from the South Sulawesi region, as well as Helaleke, Yeleli, and Musaneken sweet potatoes which are local sweet potatoes from Papua.

Sweet potato is a source of carbohydrates that are used as food. The current direction of sweet potato utilization is its function (functional food) as a health food (Ginting et al., 2011; Saputro et al., 2023). Besides being a food ingredient, it also has an important role in health. Anthocyanins in sweet potatoes have various useful functions for the body such as anti-oxidants, anti-hypertension, prevention of disorders, and liver function Jusuf (2011).

The increasing demand for anthocyanin-rich sweet potatoes as raw materials for the food industry causes the need to increase purple sweet potato yields. Ayamurasaki is a purple sweet potato clone introduced from Japan that has been cultivated in Indonesia. Apart from Ayamurasaki, there are new superior clones that have anthocyanin content and higher yield potential than Ayamurasaki, namely RIS 03063-05 and MSU 03028-10.

Cytokinin is a Plant Growth Regulator (PGR) that plays a role in stimulating plant growth. The main function of cytokinin is to stimulate cell division and promote cell enlargement. Bradshaw et al. (2009) stated that cytokinin levels rose sharply just before the initiation of sweet potato. The levels of these cytokinin remained high until the sweet potatoes were nearing maturity, then decreased. Cytokinin stimulate the formation of sweet potatoes by inhibiting starch hydrolysis activity and stimulating starch synthesis activity. Cytokinin is generally used for stem growth, while auxins are used for root growth. However, both are often needed depending on the ratio of cytokinin to auxin or vice versa (Lestari 2011).

The translocation of carbohydrates from shoots to roots Nedunchezhiyan et al. (2012). This experiment aims to study the effect of growth regulators and potassium fertilizer on the productivity of three purple sweet potato clones. The results of this study are expected to increase the productivity of purple sweet potatoes with the use of superior clones, potassium fertilizer and appropriate PGR substances.

METHODS

The experiment was carried out in the experimental garden of IPB at Leuwikopo, Dramaga, Bogor, at an elevation of 250 m above sea level (asl). The experiment was carried out for seven months from September 2013 to March 2014. The seeds used in this experiment were purple sweet potato cuttings from three clones, namely Ayamurasaki, RIS 03063-05, and MSU 03028-10. Fertilizer given were 100 kg of urea ha^{-1}, 100 kg of SP-36 ha-1, and KCl with doses according to the treatment, namely 100, 200, and 300 kg ha^{-1}. Hormax growth regulator containing auxin IAA 108.56 ppm, auxin IBA 83.72 ppm, cytokinin kinetin 98.34 ppm, cytokinin zeatin 107.81 ppm, ABA 89.35 ppm, GA3 118.40 ppm, ethylene 168 ppm, traumatic acid 212 ppm, ethylene 168 ppm , and humic acids 354 ppm. The tools used are plant cultivation equipment, hand counters, hand sprayers, meters, digital scales, and ovens.

using three factors and three replications. The first factor that became the children of the plots was the administration of growth regulator (S) consisting of two levels, namely no treatment and a concentration of 2,000-2,000 ppm. The second factor as a subplot was the application of KCl (P) fertilizer consisting of three levels, namely: 100 kg ha-1 (K2O equivalent 60 kg ha^{-1}), 200 kg ha^{-1} (K_2O equivalent 120 kg ha^{-1}), and 300 kg ha^{-1} (K_2O equivalent of 180 kg ha^{-1}). The third factor as the main plot were two sweet potato clones (K), namely: Ayamurasaki clone, RIS 03063-05, and MSU clone 03028-10. Variables observed included vegetative variables and tuber yield component variables. Vegetative variables include stem length, number of leaves, and number of branches.

The components of tuber yield include total tuber weight, healthy tuber weight, tuber weight attacked by plant pests, salable tuber weight, unsalable tuber weight, and small tuber weight. Data analysis using variance. If the results of the variance show a significant effect at the P level <0.05, then it is continued with the Duncan multiple range test (DMRT).

RESULT AND DISCUSSION

The experimental results showed that all the variable components of tuber yield were different between clones. The clones had differences in the vegetative variables of stem length, except 12 WAP and in the number of leaves, except 3 WAP. Variable number of branches did not differ between clones. The treatment factors of potassium fertilization, administration of growth regulators and the interaction of two and three treatment factors did not show a significant effect on all vegetative variables or tuber yield variables.

Effect of PGR Application on Vegetative Growth and Tubers Yield Components

PGR application did not significantly affect sweet potato vegetative growth (Table 1). High rainfall is one of the factors that affect the effectiveness of PGR. Rainfall at the time of PGR application was high [503 mm on average in September 2013 (4 MST), 394 mm in October 2013 (8 MST) and 187 mm in November 2013 (12 MST)].

Table 1. Effect of PGR application on stem length, number of leaves, and number of branches.

PGR	Age (WAP)			
ppm	3	6	9	12
	Stem length (cm)			
0	112.2	145.2	185	259.6
2000	107.9	138.4	184.5	261.2
	Number of leaves (strands)			
0	49.1	104	173.7	227.1
2000	49.3	104.6	165.2	227.4
	Number of branches			
0	5.7	9.4	10.3	11.8
2000	5.4	8.7	10.2	12.3

According to Schmidt and Ferguson's climate classification, months with rainfall > 100 mm are included in the wet months (Assyakur, 2009). The high rainfall facilitates the leaching of growth regulators that have been applied to the surface of the sweet potato plant canopy to be wasted because they are not absorbed by plants, lost through evaporation, due to washing, or carried away by rainwater (run off). Krisantini (2011) explained that the things that affect the effectiveness of growth regulators to get the desired effect, when applying PGR, attention must be paid to the type of plant and its growth phase, the type of PGR used, the weather conditions and the growing environment, as well as the technical culture of the plants in the field.

Table 2 shows that the percentage of tubers attacked by pests that were treated with PGR 2,000 ppm was lower than the control treatment. Healthy tubers were induced more in PGR-treated plants compared to controls. The condition of the plants that were given PGR resulted in the induction of flavonoids as raw material for anthocyanins in tubers.

Table 2. Effect of giving PGR on tuber yield components.

Tuber yields	0 ppm (g $(7m^2)^{-1}$)	%[b]	2000 ppm (g $(7m^2)^{-1}$)	%[b]
Total tubers	999.6		1116.4	
Healthy tubers	985	96.2	1097.5	99.6
Tubers attacked by pest	14.4	3.7	33.8	0.4
Tubers fit for tubers	552	52.5	588.1	46.7
Tubers not fit for sale	447.3	47.4	542.9	53.3
Small tubers	432.9	43.7	509.2	52.9

Note: Total tuber is the total tuber weight; Healthy tubers are tubers worth selling and small tubers that are free from pest attack; Tubers fit for sale are healthy tubers measuring > 100 g; Tubers unfit for sale are bulbs attacked by pest and small tubers; Small tubers are tubers weighing < 100 g; b Percentage to total tubers.

The anthocyanins that are formed make the purple sweet potato's defense against pest attacks stronger and the plants healthier. Anthocyanins are secondary metabolites of the flavonoid group. Anthocyanin is a chemical substance that functions directly as a repellent and indirectly as a visual signal. Anthocyanins also function as anti-inflammatory and anti-candida (Sucharat et al., 2016). This is reinforced by the statement of Werlein et al. (2005) that anthocyanins can protect plants from infections caused by pathogenic microorganisms. The antimicrobial activity of anthocyanins is slightly more effective than other phenolic compounds such as hydroxycinnamic acids which can also be produced in the roots (Werlein et al., 2005).

The Effect of Potassium Application on Vegetative Growth and Tubers Yield Components

Based on Table 3, the application of potassium fertilizer has no significant effect on the growth of sweet potatoes. Vegetative growth that occurred in this experiment is thought to be more influenced by the factor of water availability through high rainfall.

Table 3. Effect of potassium fertilization on stem length, number of leaves, and number of branches.

Fertilizer dosage (kg ha^{-1})	Age (WAP) 3	6	9	12
	Stem length (cm)			
60	114.7	143.2	185.1	252.9
120	111.1	145	190.9	266.5
180	104.4	137.2	178.3	261.8
	Number of leaves (strands)			
60	53.9	98.7	151.9	226.8
120	45.9	118.6	182.3	228.5
180	47.8	95.7	174.2	226.4
	Number of branches			
60	5.8	7.9	10.2	11.8
120	5.2	9.9	10.5	11.9
180	5.7	9.3	10	12.4

The nitrogen content remained low (0.18%) at the beginning and at the end of planting after fertilization. This is because the nitrogen provided is used by plants and some of it is washed away by rainwater. Rainfall also has an impact on nitrogen levels in the soil which causes the growth of the sweet potato plant canopy to become larger. This assumption is reinforced by Rasyid's statement (2010) that the interaction treatment of water and nitrogen fertilizers on corn plants gave a significant increase in corn plant growth (plant height, cob weight, chestnut weight, total plant dry weight, N content, and N uptake).

Potassium fertilization has not significantly increased tuber yield (Table 4). This is presumably because the dose given is still not pestimal to increase tuber yield. Research on potassium fertilization in Kenya showed that the highest weight of potato tubers of the Ajiba variety was 1.14 kg per plant and the productivity was 49.38 tons ha^{-1} with the addition of 300 kg K_2O ha^{-1} (Zelelew & Ghebreslassie, 2016). Potassium K_2O given in the experiment was still lower with a dose of 60 kg ha^{-1} to 180 kg ha^{-1}. Sweet potato yield will increase proportionally with increasing available potassium that can be absorbed by plants. This is related to the function of the element potassium, which is to transport photosynthate from source to sink. This is reinforced by the statement of Pahlevi et al. (2016) that potassium plays an important role in the tuber enlargement process because of its participation in the assimilation translocation process from the source to the tuber storage.

Table 4. The effect of potassium fertilizer doses on tuber yield components.

Tubers yield (g (7m^2)$^{-1}$)	60 kg ha^{-1}	%^{b}	120 kg ha^{-1}	%^{b}	180 kg ha^{-1}	%^{b}
Total tubers	843,1		1122,4		1208,6	
Healthy tubers	839,4	99,6	1079,7	96,2	1204,6	99,7
Tubers attacked by pest	3,6	0,4	41,2	3,7	27,6	2,3
Tubers fit for tubers	393,6	46,7	588,8	52,5	727,8	60,2
Tubers not fit for sale	449,4	53,3	531,7	47,4	504,3	41,7
Small tubers	445,8	52,9	490,5	43,7	476,8	39,5

Potassium fertilizers may have been leached by high rainfall of 503 mm in September 2013 at 1 MST fertilizer application and 394 mm in October 2013 at 6 MST fertilizer application. This causes the availability of K_2O content in the soil to decrease. Potassium was available in the soil although its value increased from 0.23 me 100 g^{-1} before treatment to 0.77 me 100 g^{-1} after treatment. However, the addition of potassium does not increase the yield component of the tuber because the roots are less able to absorb potassium in the soil. This is thought to be due to excess water in the soil. High rainfall causes too much crown growth, causing competition between the crown and tubers as a sink. This is confirmed by the experiment of Wandana et al. (2012) regarding the application of potassium fertilizer to sweet potato plants which did not significantly affect tuber weight due to environmental influences in the form of high rainfall during application, namely 204.1 mm in March and 144.2 mm in April 2012. Effect of high rainfall on tuber yield related to the low number of tubers, namely inhibition of tuber initiation. The decrease in weight per tuber is thought to be due to the lack of assimilate translocated to the tubers and the slow activity of the primary cambium. The size of tubers in the field is basically greatly influenced by the first 20 days after planting. Suwarto et al. (2006) explained that the period between root formation at 4 WAP and the beginning of tuber formation at 8 WAP will increase the capacity of sweet potato plants to absorb nutrients in the root area.

Vegetative Growth and Yield Components of Various Clone

Clone RIS 03063-05 showed low adaptability at the start of planting (1 WAP) (Table 5), and based on Table 6 clone RIS 03063-05 had the lowest yield component in the field. In the first week of planting, it rarely rains, so every day watering is done to the seeds that have been planted. Several cuttings of clone RIS 03063-05 died due to drought even though they had been watered for the first week after planting. Most of the surviving cuttings experience drying of the leaves to the point where they first defoliate and then form new leaves. Seeds that experienced death were embroidered in the first and second weeks. In the second week it rains more frequently so that the soil is sufficiently moist and plant growth is evenly distributed.

Table 5. Stem length, number of leaves, and number of branches of various clones.

Clone	Age (WAP) 3	6	9	12
	Stem length (cm)^a			
Ayamurasaki	91.8a	122.2b	172.1b	237.6
RIS 03063-05	80.2b	113.6b	156.0b	231.3
MSU 03028-10	158.2a	189.7a	226.1a	312.3
	Number of leaves (strands)^a			
Ayamurasaki	51.7	74.9b	125.7b	180.7b
RIS 03063-05	50.7	76.0b	143.5b	194.8b
MSU 03028-10	51.7	162.1a	239.1a	306.2a
	Number of branches			
Ayamurasaki	6.2	9.9	10.9	12.4
RIS 03063-05	5.9	9.4	10.8	12.3
MSU 03028-10	4.6	7.9	9	11.4

Note: a: Numbers followed by the same letter on the same line are not significantly different on the 5% DMRT follow-up trial.

The Ayamurasaki clone had good adaptability at the start of growth (1 WAP) and had the largest number of salable cassava (Table 6). At the beginning of 1 MST growth, the Ayamurasaki and MSU 03028-10 clones did not drop their leaves first, continued to grow and form new leaves. Early growth of MSU 03028-10 clone showed good adaptation and faster stem elongation than the other two clones. This can be seen in the third week, clone MSU 03028-10 had the longest stem, and so did the following weeks (Table 5). MSU clone 03028-10 had the highest number of total tubers and healthy tubers of the other two clones (Table 6). The yield value of salable tubers of the MSU 03028-10 clone was not significantly different from that of the Ayamurasaki clone. However, if the desired consumer preference is for coloring in the food industry, the MSU 03028-10 clone (590.8 mg 100 g^{-1} BB) is more profitable to develop because it has a higher anthocyanin content than the Ayamurasaki clone (281.90 mg 100 g^{-1} BB). . Anthocyanin pigments are natural dyes that cause red, orange, purple and blue colors. Anthocyanin pigments are mostly found in flower

Table 6. Components of tuber yields of various clones.

Tubers yield	(g (7m^2)$^{-1}$)^a (ayamurasaki)	%^{b}	(g (7m^2)$^{-1}$)^a (RIS 03063-05)	%^{b}	(g (7m^2)$^{-1}$)^a (MSU 03028-10)	%^{b}
Total tubers	1531,7a		104,6b		1537,8a	
Healthy tubers	1489,0a	97,2	104,6b	100	1529,9a	99,5
Tubers attacked by pest	41,1a	2,9	0,0b	0	31,3ab	2,0
Tubers fit for tubers	872,4a	57	17,2b	16,4	820,6a	53,4
Tubers not fit for sale	657,7a	42,9	87,4b	83,6	740,3a	46,1
Small tubers	616,6a	40,3	87,4b	83,6	709,0a	46,1

Note: Total tuber is the total tuber weight; Healthy tubers are tubers worth selling and small tubers that are free from pest attacks; Tubers fit for sale are healthy tubers measuring > 100 g; Tubers unfit for sale are tubers attacked by pest and small tubers; Small tubers are tubers weighing < 100 g. a Number followed by the same letter on the same line are not significantly different on the 5% DMRT follow-up trial.

crowns. This pigment can also be extracted from several plant organs from tubers, leaves to fruit, such as purple sweet potato (Saati, 2016). Purple sweet potato can be used as a natural dye. The use of natural dyes such as anthocyanins is increasingly in demand because it can reduce the use of synthetic dyes which are toxic and not environmentally friendly. Anthocyanins are also used in the manufacture of nutritional supplements because they have many positive impacts on human health. In Japan, anthocyanins are not only used as food coloring, but also used as paper coloring (Awobana paper) (Bechtold and Mussak, 2009).

CONCLUSION

Provision of 2,000 ppm of growth regulator applied at 4, 8, and 12 WAP was not able to increase vegetative growth and tuber yield components. Application of K_2O fertilizer 60 kg ha^{-1} to 180 kg ha^{-1} has not been able to increase tuber growth and yield. There are differences in tuber production between clones. MSU 03028-10 clone had the best tuber yield components, namely total tubers, healthy tubers, unfit tubers and small tubers. Clone MSU 03028-10 had the longest stem and the highest number of leaves. There was no interaction between the two and three treatment factors in increasing growth and tuber yield components.

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