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EFFECT OF POTASSIUM APPLICATION ON GROWTH AND YIELD OF SWEET POTATO VARIETIES (IPOMOEA BATATAS L.)

Garfansa Marchel Putra*, **Sudiarso**, **Suminarti Nur Edy**
Faculty of Agriculture, University of Brawijaya, Malang, Indonesia
*E-mail: marchel.opg@gmail.com

ABSTRACT
In Indonesia, which is a tropical country, sweet potatoes can grow on almost all islands in Indonesia. Sweet potatoes have various varieties. Sweet potato plants are known to be very responsive to potassium. It is hoped that through this research information will be obtained about the proportion of appropriate potassium fertilizer in each variety tested so that the productivity of sweet potato plants can be increased. A field experiment conducted using a Split Plot Design was repeated three times. The main plot was Varieties (V), i.e. Gunung Kawi and Cilembu Varieties. The sub plot was dose of KCl (K) fertilizer consisting of five doses, i.e. K0 = 0 kg ha^{-1}, K1 = 78 kg ha^{-1}, K2 = 137 kg ha^{-1}, K3 = 196 kg ha^{-1} and K4 = 255 kg ha^{-1}. The results showed that there was a positive interaction between the productivity of sweet potatoes with KCl doses in the Gunung Kawi and Cilembu varieties. The treatment of KCl 196 kg ha-1 gave favorable results for the varieties of Gunung Kawi and Cilembu at 28.7 t ha-1 and 16.3 t ha-1.

KEY WORDS
Sweet potato, environment, fertilizer, variety, productivity, potassium.

Sweet potato plant is easily cultivated by farmers. In Indonesia, sweet potatoes can be grown on almost all islands in Indonesia (Yaningsih et al, 2013). Besides being used as an alternative food, sweet potatoes can also be processed into various forms of products such as flour and cosmetic ingredients, while the waste can be used for animal feed. This causes sweet potato plant to become one of the important commodities in Indonesia (Jusuf and Erliana, 2014). However sweet potato productivity at the national level has decreased by 89 tons from 2013-2015 and is predicted to continue to decline every year . Onunka et al. (2012) confirmed that yields of sweet potato is presently restricted by many factors among which are low soil fertility, varietal selection, planting date, weather condition, soil type, weed, insect and disease pressure and crop management practices among others. Various ways have been conducted to increase the yield of sweet potatoes such as improving soil fertility and plant maintenance methods, especially in the application of fertilizer and using suitable variety.

Potassium fertilizer is known to have a role in improving the quality and quantity of sweet potato plants (Pushpalatha et al, 2017) because of its function that affects tuber formation (Dkhil et al, 2011). Zelelew et al, (2016) reported that K fertilizer with 300 kg ha^{-1} produced the best yield of sweet potato from *ajiba* variety. Another research found that sweet potato responded to K application up to the 160 kg ha^{-1} rate based on improved growth, tuber yield and tuber appearance (Uwah et al, 2013).

The rapid development of sweet potato plants is not only shown in the processed products produced but the creation of various sweet potato varieties that can excel in terms of appearance and content. Selection and selection of varieties needs to be done to get the potential desired by farmers (Trustinah and Iswanto, 2014). Cilembu and Gunung Kawi varieties are local varieties that are often cultivated in Indonesia. Cilembu variety is popular among the community because of its high sweetness and nutrition. The average sugar content of Cilembu tubers ranges from 5.39% - 6.97% in the raw state, while the sugar content in regular sweet potato tubers is only about 2.38% causing Cilembu tubers to have high sweetness. On the other hand there is a variety of Gunung Kawi where the sweetness level almost resembles the tubers produced by Cilembu variety. Gunung Kawi varieties have high carbohydrate and anthocyanin pigments. In addition, Gunung Kawi varieties have more tuber yield than other sweet potato varieties, causing Gunung Kawi variety to be favored by farmers (Suhardi et al., 2016)

In order to obtain good yield, studies must be conducted on improved varieties of crops which normally do require higher quantities of fertilizers with corresponding higher yield compared to the local varieties. The objective of this study was to select a suitable sweet potato variety between the two and determine the optimum dose of K fertilizer for its production.

MATERIALS AND METHODS OF RESEARCH

This research was conducted from September 2017 to January 2018 in Dadaprejo Village, Semanding Subdistrict, Malang, East Java in the middle plains with an altitude of 520 meters above sea level and temperatures between 27 ° C - 29 ° C. Percentage physic soil experiment before planting: 20% sandy, 48% dusty, 32% loamy and available K: 0.14 ppm. Research design, treatment and data collection factorial experiment was arranged in a split plot design and repeated three times. The main plot was sweet potato variety (V), while the sub plot was the dose of KCl. The main plot consisted of two sweet potato varieties, V1 = Gunung Kawi Variety and V2 = Cilembu Variety. The sub plot was dose of KCl (K) fertilizers which consisted of five types, K0 = 0 kg ha^{-1} (control), K1 = 78 kg ha^{-1}, K2 = 137 kg ha^{-1}, K3 = 196 kg ha^{-1} and K4 = 255 kg ha^{-1}. The sweet potato were planted on farming area of 570 m^2 by spacing 75 x 25 cm. There were 30 treatment plot comprised of beds of 3 x 3.2 m in size. The first stage of K fertilizer were applied at 7 days before planting, the second stage were repeated once in 14 days after planting. experiment replicated ten plots and repeated three times, so there were 30 experimental plot units. The observation was done on leaf area (cm^2 $plant^{-1}$) and total dry weight (g $plant^{-1}$) which observed at 20, 40, 60 and 80 days after planting. The destructive observation include fresh tuber (ton ha^{-1}) at the age of the plant 120 days after planting. estimation of potassium absorption. Leaf area was measured using a Leaf Area Meter-211.

Analysis of soil chemical properties carried out at the Chemical Laboratory of the Soil Department, Faculty of Agriculture, Brawijaya University, Malang included physic texture of soil, K and Mg (HCl 25% method) at 3 stage they are before planting, mid cropping, and after harvest. The Estimates available of K and Mg were calculated used the following formula:

$$Estimates\ available\ nutrient\ (\%) = \frac{Available\ Nutrient\ in\ mid\ cropping - available\ Nutrient\ after\ harvest}{Available\ Nutrient\ in\ mid\ cropping} x100\%$$

Data analysis used analysis of variance with a 5% F test to indicate whether the data had a significant interaction or there were no significant differences in treatment. If the result of F count> F table means that the data is significantly different and continued with HSD test at level 5% (Gomez and Gomez, 1995). Besides, regresion tests were also conducted to determine the relationship between treatments.

RESULTS AND DISCUSSION

Leaf Area. The development of leaf area under all treatment combinations is presented in Table 2. The value of leaf index indices of varieties and dose of KCl showed significant differences (P <0.05) at the age of 40, 60 to 80 DAP. At 80 DAP, plants with control treatment showed a significantly lower leaf area compared with 137 Kg ha-1, 196 Kg ha-1, and 255 Kg ha-1 KCl. Similar things were also seen in the Cilembu variety with KCl 196 Kg ha-1, the leaf area produced was significantly more than the control but not significantly different from other treatments. The lack of nutrients, especially potassium which is available to plants, results in inhibition of the physiological activities of plants. Potassium element can trigger plant growth because of its function in elongation and widening of vegetative organs. This statement is in accordance with Dkhil (2011), which shows potassium fertilizer gives significant results on the development of vegetative organs compared to the control treatment due to cell enlargement and elongation. The availability of low K elements also causes the formation of assimilate to be disrupted which will later be used for the formation of plant organs such as leaves (Chuan, 2017).

Table 1 – Estimation K and Mg absorption by plant

Treatments	Nutrient content (%)	
	Mg	K
V1K0 (Gunung Kawi: 0 Kg ha^{-1} KCl)	11 %	25 %
V1K1 (Gunung Kawi: 78 Kg ha^{-1} KCl)	12 %	24 %
V1K2 (Gunung Kawi: 137 Kg ha^{-1} KCl)	11 %	41 %
V1K3 (Gunung Kawi: 196 Kg ha^{-1} KCl)	10 %	50 %
V1K4 (Gunung Kawi: 255 Kg ha^{-1} KCl)	9 %	54 %
V2K0 (Cilembu: 0 Kg ha^{-1} KCl)	15 %	26 %
V2K1 (Cilembu: 78 Kg ha^{-1} KCl)	14 %	35 %
V2K2 (Cilembu: 137 Kg ha^{-1} KCl)	14 %	51 %
V2K3 (Cilembu: 196 Kg ha^{-1} KCl)	8 %	60 %
V2K4 (Cilembu: 255 Kg ha^{-1} KCl)	7 %	57 %

Table 2 – Interaction between Varieties and KCl to Leaf Area (cm^2 plant^{-1}) of Plants at 40, 60 and 80 DAP

DAP	Treatments	Dose of KCl (Kg ha^{-1})				
		Control	78 Kg ha^{-1}	137 Kg ha^{-1}	196 Kg ha^{-1}	255 Kg ha^{-1}
40	Gunung Kawi	1833.3 a B	2233.7 ab B	2486.7 bc B	2506.7 bc B	2905.7 c B
	Cilembu	1465.2 a A	1504.7 a A	1548.3 a A	1900.2 ab A	2119.7 b A
	HSD 5%	565				
60	Gunung Kawi	2801.3 a A	2843.7 a A	3276.3 a A	5960.7 b B	6036.7 b A
	Cilembu	1929.7 a A	2635.3 ab A	3668.4 ab A	3252.3 ab A	4916.3 b A
	HSD 5%	2661				
80	Gunung Kawi	3269.7 a A	5374.7 ab A	6174.2 b A	7486.3 b B	6331.2 b B
	Cilembu	2158.3 a A	2300.3 ab A	3970.7 ab A	4804.7 b A	3625.3 ab A
	HSD 5%	2567.4				

Note: Numbers with the same lowercase letters in the same row and the same upper case in the same column show not significant difference in HSD test (P<0.05), DAP = days after planting.

When reviewed by the effect of KCl on both varieties, giving 196 Kg ha-1 and 255 Kg ha-1 wider leaf area was obtained in Gunung Kawi variety. This is quite reasonable when viewed based on the leaf type owned by Gunung Kawi variety is round and oval with wider leaf area. Whereas the Cilembu variety has a leaf type with a lower leaf area which causes Gunung Kawi to have a wider leaf area. This can be seen from the observation of the leaf area produced where the Gunung Kawi variety produces wider leaf area than Cilembu (Table 2). The statement explains that the large number of leaves formed is not always followed by the total width of the plant leaves. Leaf size per individual plant for each variety is different. The Cilembu variety has a relatively larger number of leaves with the breed type whereas for Gunung Kawi the is oval with a wider leaf area. Each variety planted has different leaf characteristics. The difference in morphology will be obvious if planted in the same environment (Rahayu et al, 2010). In sweet potatoes themselves for different varieties will show different results in leaf area and will certainly affect the results of the analysis of the fresh weight of the plant (Yusnita, 2010). From these genetic differences, optimum nutrient requirements and environmental conditions will be different for each variety later. To see how far the relationship between KCl fertilizer (X) and leaf area (Y) of both sweet potato varieties was correlated, regression analysis was carried out (Figure 1a). Regression analysis for the Gunung Kawi variety shows Y = -0.0874X2 + 35.802X + 3159.7, R^2 = 0.93 whereas for Cilembu the regression equation is Y = -0.0477X2 + 20.512X + 1862.5, R^2 = 0.72. Based on these equations it can be seen that the Gunung Kawi variety in KCl fertilization 210 Kg ha-1 will obtain a leaf area of 6823 cm2. Whereas for Cilembu variety on KCl fertilization of 216 Kg ha-1, a leaf area of 4067 cm2 will be obtained and if it exceeds the dose, the leaf area will be reduced. The determinant coefficients on the Cilembu and Gunung Kawi varieties were 0.72 and 0.93, which means about 72% and 93% of the leaf area produced in the Cilembu and Gunung Kawi varieties were influenced by KCl fertilizer.

Total Dry Weight. The amount of assimilation produced by plants can be described by measuring the total dry weight of the plant. Table 3 shows that at the age of 80 days in the Gunung Kawi variety, when the addition of KCl fertilizer was carried out from 78 Kg ha-1 to 255 Kg ha-1, the dry weight produced was significantly higher than the control treatment, while the Cilembu variety for control and 78 Kg ha-1 dry weight produced was significantly lower than 137 Kg ha-1 and 196 Kg ha-1. The low dry weight produced shows the low nutrients available to plants that cause the formation of physiological organs of the plant to be inhibited. Assimilate formation is strongly influenced by vegetative organs of plants such as leaves that are used as the place for the photosynthesis process. Plant dry weight is a picture of the result of translocation of photosynthate to all parts of the plant as a process of photosynthetic rate in leaves in intercepting solar radiation (Madhu and Jerry, 2016). This is enough to explain that the low KCl fertilizer can affect the formation process of the assimilate itself. It is known that assimilation is energy that will be used for 3 activities in plants, namely: (1) some energy will be used as growth energy, (2) some will be stored as food reserves, and (3) some of the energy will be stored as sinks which is a form of economic yield of plants. The extent to which the relationship between KCl fertilizer (X) and the total dry weight of the plant (Y) can be seen from the regression test (Figure 1b). Based on these equations it can be seen that the Gunung Kawi variety when fertilizing KCl 176 Kg ha-1 was carried out to obtain a plant dry weight of 127 g. Whereas for Cilembu varieties on KCl fertilization of 168 Kg ha-1, the plant's dry weight will be obtained at 109 g and if it exceeds this dose it will reduce the dry weight of the plants produced. The determinant coefficients on the Cilembu and Gunung Kawi varieties were 0.82 and 0.99 which means that 82% and 99% of the dry weight produced in the Cilembu and Gunung Kawi varieties were influenced by KCl fertilizer.

Table 3 – Interaction between Varieties and KCl to Total Dry Weight (g plant^{-1}) of Plants at 40, 60 and 80 DAP

DAP	Treatments	Dose of KCl (Kg ha^{-1})				
		Control	78 Kg ha^{-1}	137 Kg ha^{-1}	196 Kg ha^{-1}	255 Kg ha^{-1}
40	Gunung Kawi	42.7 a A	69.1 bc A	48.2 ab A	96.3 d A	86.1 cd B
	Cilembu	48.47 a A	48.7 a A	70.1 ab A	81.1 b A	57.8 ab A
	HSD 5%	25.5				
60	Gunung Kawi	54.7 a A	76.9 b A	79.2 bc A	109.1 c B	97.7 c A
	Cilembu	58.3 a A	60.4 a A	93.4 b A	87.3 b A	103.3 b A
	HSD 5%	20.6				
80	Gunung Kawi	76.7 a A	113.6 b B	122.6 b A	128.4 b A	119.1 b A
	Cilembu	83.1 a A	87.8 a A	112.2 b A	120.3 b A	98.2 ab A
	HSD 5%	23.5				

Note: Numbers with the same lowercase letters in the same row and the same upper case in the same column show not significant difference in HSD test (P<0.05), DAP = days after planting.

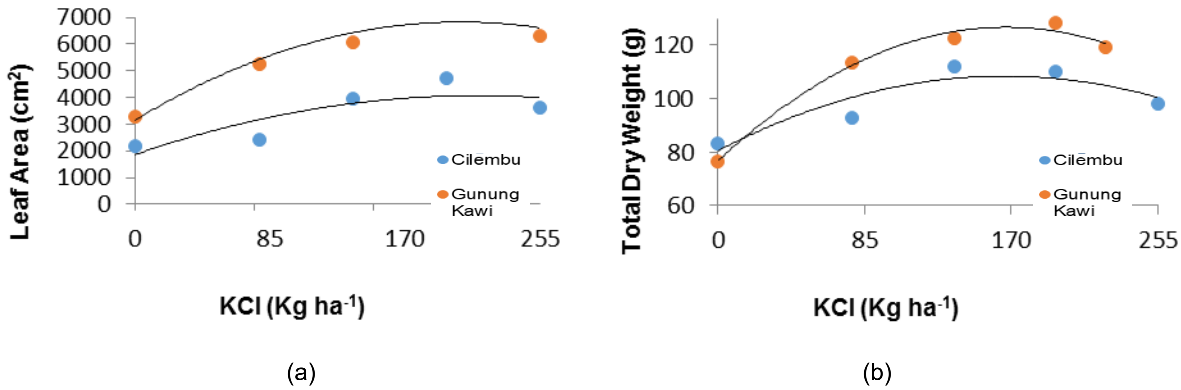

Figure 1 – The effect of KCl toward total dry weight and leaf area on sweet potato varieties (a) relationship between KCl toward leaf area, Gunung Kawi varieties Y = -0.0874X2 + 35.802X + 3159.7, R^2 = 0.93 and Cilembu varieties $Y = -0.0477X^2 + 20.512X + 1862.5$, R^2 = 0.72. (b) relationship between KCl toward total dry weight, Gunung Kawi varieties $Y = -0.0016X^2 + 0.5624X + 77.211$, R^2 = 0.99 and Cilembu varieties $Y = -0.001X^2 + 0.3359X + 80.504$, R^2 = 0.82.

Tuber Yield. The growth component will affect the yield components of a plant. The existence of a good growth phase, will be followed by a good generative phase in which the plant's generative organs will grow well and the plants can produce good results. In this study, the results for sweet potato plants of Gunung Kawi variety which were not given KCl fertilizer were significantly lower yields of 8.3 tons ha-1 (46%) and 10.9 tons ha-1 (61%) compared to KCl dose 137 Kg ha-1 and 196 Kg ha-1. The low yield is thought to be due to the lower K uptake by plants without KCl fertilizer (35%) when compared to plants in KCl fertilizer 137 Kg ha-1 (41%) and 196 Kg ha-1 (50%). The same thing was shown in the yield of Cilembu variety where for plants that were not given KCl fertilizer showed significantly lower yields with an estimated absorption of 32%, compared to KCl fertilization 78 Kg ha-1 (35%), 137 Kg ha-1 (51 %) and 196 Kg ha-1 (60%). This is enough to prove that the size of the impact given to sweet potato plants in the tuber formation process is influenced by the availability of K elements contained in the soil. As previously explained, the formed tubers originate from developments that occur in young roots under conditions of low temperature and high supply of potassium (Kolowski, 1977). Considering the addition of KCl fertilizer in the soil can increase the availability of K elements in plants and the element K plays an important role in the formation of tubers so that the addition of KCl fertilizer can increase the harvest of tubers (tons ha-1). It is also shown in the observation of other harvest components such as the number of tubers, tuber weight, tuber diameter, and tuber length. Even so, when giving KCl improved both Gunung Kawi and Cilembu varieties from 196 Kg ha-1 to 255 Kg ha-1, the yield of tons of ha-1 obtained was not significantly different compared to other treatments. This is suspected wiith 255 Kg ha-1 KCl, the element K absorbed by the plant has exceeded the optimum dose needed in the tuber formation process. Please note that tubers in absorption K are plants that are luxury consumption which means that plants will absorb K excessively in the soil to be stored in tendrils and will not be used for the metabolic processes of plants. This will have an impact on the level of absorption of K in the soil but not followed by an increase in the production of yields obtained. The supply of potassium in the soil can be reduced, because of three things: taking potassium by the plant, washing potassium by water, and soil erosion. In general, the role of potassium is related to metabolic processes, such as photosynthesis and respiration.

Various doses of KCl fertilizer in various varieties, Gunung Kawi produce higher yields than Cilembu. This is quite understandable on every different variable. The ability of sweet potatoes is in the form of tubers other than by environmental factors as well as by plant factors themselves. As previously explained, the Gunung Kawi variety has a different morphology compared to Cilembu. The Gunung Kawi variety has a round leaf morphology with a leaf density level that will be greater than the radiation interception that will produce more, namely better and more growth rates. Unlike the Cilembu variety which has the characteristics of leaf leaves with leaf area more intense and has a high leaf density. This led to the study of Zhang et al. (2018), which states that the existence of light interception is based on wide optimization followed by photosynthesis and the resulting biomass. Optimal photosynthesis will produce photosynthate which is also good for the formation of tubers well. This shows that the Gunung Kawi variety is able to capture sunlight better than Cilembu. The high vegetative phase level (leaves) results in the least amount of carbohydrates left for tuber development (Saitama, 2017). Isa et al. (2015), in his study also explained the inhibition of tuber formation due to growth in the high vegetative phase. Based on Table 4 also shows that when fertilizer is increased to 255 kg ha-1, yields decrease and the results obtained show a value that is not significantly different from other treatments. Interim estimates that can be understood that in 255 Kg ha-1 KCl, the availability of Mg in the soil cannot be fully absorbed by plants due to the high K element (Table 1). As previously explained, high potassium will affect the level of availability of Mg. Increasing the amount of K in the soil will cause Mg to become chelated to decrease the element of Mg. Potassium is known as an element that is antagonistic to magnesium (Mg). This is consistent with Ding's (2006) statement, which explains that the addition of excess K elements to plants will cause antagonistic effects between elements K and Mg so that Mg availability becomes low. Another opinion suggests that when the K element content in the soil is excessive, it is likely that some elements of Mg2 + and Ca2 + will be retained and replaced by K + ions causing dissolution of Mg and Ca elements (Bolan et al., 2005). If Mg is bound to the soil in the presence of a high KCl application, photosynthesis will decrease due to the function of chlorophyll as a light absorbent. In Ding Yu Chuan's research (2008), showed that the low element of Mg will have an impact on the decrease of chlorophyll content and photosynthetic activity causing the formation of assimilates to be inhibited so that the bulb enlargement will decrease. Chlorophyll is an important key in photosynthesis, so that with increasing chlorophyll will increase photosynthetic activity which affects the yield and growth of plants (Subaedah et al, 2016). In the description above, it has been explained the important role of element K. Therefore, if the plant has K deficiency, it can inhibit the photosynthesis process, as well as the assimilation translocation process. The main role of potassium is in its ability as a catalyst. In a plant's life cycle, fertilizer will greatly affect the growth and development of plants and the crops that will be obtained.

Table 4 – Interaction between Varieties and KCl on Yield (ton ha^{-1}) of Plants

Treatments	Dose of KCl (Kg ha^{-1})				
	Control	78 Kg ha^{-1}	137 Kg ha^{-1}	196 Kg ha^{-1}	255 Kg ha^{-1}
Gunung Kawi	17.8 a B	20.7 ab B	26.1 bc B	28.7 c B	23.1 abc B
Cilembu	8.3 a A	14.5 b A	15.2 b A	16.3 b A	13.6 ab A
HSD 5%	5.7				

Note: Numbers with the same lowercase letters in the same row and the same upper case in the same column show not significant difference in HSD test (P<0.05).

CONCLUSION

This study has demonstrated that sweet potato responded to K application up to the 196 kg ha^{-1} rate based on improved leaf area, total dry weigth and tuber yield. The application of K fertilizer 196 kg ha^{-1} produced the best tuber yield per hectare at both variety, Cilembu 16.3 t ha^{-1} and Gunung Kawi 28.7 t ha^{-1}. The application of K at 196 kg ha^{-1} appeared appropriate for optimum yield in our study area. Production of sweet potato on these soils would therefore require K in the fertilizer regime unless the pre-planting soil test result is shown to be adequate in potassium.

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