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Effect of potassium fertilizers doses on the growth, tuber yield, and resistance to weevil infestation of sweet potato on Latosol soil

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Abstract

Major problems in sweet potato (*Ipomoea batatas* L.) cultivation are low yield and high weevil (*Cylas formicarius*) infestation. The effect of potassium (K) on growth and yield has been intensively reported. However, there is less information on the correlation between K and the resistance to weevil infestation. The aim of the research was to determine the optimum dose of K fertilizers for maximum tuber yield and minimum weevil infestation Sweet potato var. Ase Kapas was planted with a K dose of 0, 45, 90, 135, and 180 kg K_2O ha^{-1}. The experiment was conducted using a randomized block design with 4 replications in January – July 2020 at Latosol soil. The experimental plot was 4m x 2m which was divided into 4 ridges. Stem cuttings were planted on the center of the ridge with a 0.20 m spacing. Variables of growth, tuber yield, and level of weevil infestation were observed at 3 weeks after planting and at harvest. There were significant quadratic responses of yield variables to the K application. It is recommended the use of 125 kg K_2O ha^{-1} can provide the highest tuber yield and a significant reduce of weevil infestation level. At the K dose of 125 kg K_2O ha^{-1} , tuber yield increased by 179 % (357.4 g $plant^{-1}$, compared to the control of 127.9 g $plant^{-1}$) and the weevil infested tuber was reduced as much as 61.6 % (from 6.46, at the control dose to 2.37 tuber $plant^{-1}$).

Keywords: Cylas formicarius, Ipomoea batatas L., K dose, marketable tuber.
Abbreviations*:* K2O_potassium oxide*.*

Introduction

Sweet potato (*Ipomoea batatas L.*) is a source of food in the world. It is at seventh rank in the term of production by 91.8 million tons in 2019 (FAO, 2021). However, in the period of 2010-2019, the production tended to decrease (Shahbandeh, 2021). Major problems related to the production are low soil nutrient availability and high intensity of sweet potato weevil (*Cylas formicarius*) infestation. For better growth and high tuber yield, sweet potato needs a large amount of potassium (K) nutrients (Aboyeji et al., 2019) as an important macronutrient (Hafsi et al., 2014). *C. formicarius* is a disastrous and serious insect pest of sweet potato worldwide (Hue and Low, 2015; Korada et al., 2010), the most harmful pests in major areas of production in warm climates (Liao et al., 2020), and very difficult to control (Laraki, 2014). An approach for control *C. formicarius* is implementing integrated pest management. One of the approaches is a culture technique (Korada et al., 2010) such as the right in fertilizing.

Potassium (K) involves in many plant physiology processes including photosynthesis, assimilate translocation, synthesis of protein, regulation of plant stomata, turgor maintenance, control of ionic balance, water use efficiency, activation of plant enzymes, and stress tolerance (Aboyeji et al., 2019). Klipcan et al. (2020) reported that K increases the thickness of sweet potato skin by adding one phellem layer and enlarged the size of the cells. K is needed more than nitrogen (N) and phosphorous (P). The average of N, P, and K removed from the soil by sweet potato were 61, 13.3, and 97 kg ha^{-1}, respectively (Tan, 2015).

The application of K fertilizers in China varied from 150 - 300 kg K_2O ha^{-1} (Jian-Wei et al., 2001) and on Ultisol soil of Calabar ranged of 120 - 160 kg K_2O ha^{-1} (Uwah et al., 2013). For a better response of applied K, their optimum limits must be determined based on the soil characteristics and plant needs (Aboyeji et al., 2019). Determining the optimum K application will be more important because farmers often face the problem of procuring K fertilizers due to the lack of availability and expensive price.

The study related to the effect of K nutrients on growth and tuber yield has been intensively reported. However, the information on relation of K fertilizers application and the resistance of sweet potato to weevil infestation are scarce. Teli and Salunkhe (1996) reported that skin thickness influences sweet potato weevil infestation. Based on the result of Klipcan et al. (2020) the K nutrient increased the thickness of sweet potato skin, it is hypothesized that the increase of K fertilizers will be followed by the resistance of weevil infestation which is novelty of this research. The objective of this research was to determine the optimum K fertilizers dose on the tropical Latosol soil both for maximum growth and tuber yield and minimizing weevil infestation of sweet potato.

Results and discussion

The Latosol soil had high available K (0.59 cmol K kg-1) and other chemicals (Table 1). The experiment was conducted at rainy seasons with the average rainfall of 401.2 mm month^{-1} and warm climate (Table 2). The growth, tuber yield, marketable tuber, and weevil infestation of sweet potato were significantly affected by the level of K fertilizers dose. The warm climate with an average temperature of 26.4 ^{o}C was suitable for sweet potato weevil attacks (Liao et al., 2020).

Plant growth responses

Sweet potato growth in terms of the number of branches and leaves and aboveground fresh biomass significantly linearly increased with the increased level of K fertilizers dose. Figure 1 shows the responses of the number of branches and leaves at 3 WAP and aboveground fresh biomass at harvest. The analysis result of orthogonal polynomial and regressions of responses of the variables to the rate of K fertilizer doses are shown on Table 3. A similar effect of K nutrient on the sweet potato growth was reported by Scott (1950) that the branches and leaves uptake the most of the K nutrient in the third month, and tubers uptake the most K nutrient in the fourth and fifth months. Up to the rate K2O of 180 kg ha^{-1}, the growth variable inceased. Byju and George (2005) reported that potassium can be transported by sweet potato tubers from the soil up to 360 kg ha^{-1}.

One of the physiological processes influenced by K nutrient is photosynthesis (Aboyeji et al., 2019). Potassium fertilizing increases the rate of liquid photosynthesis (Simões et al., 2020). There was a positive response to photosynthesis of sweet potato to the increase of K fertilizers dose by increasing photosynthesis apparatus such as the number of branches, leaves, and chloroplast (Singh et al., 2017). Majumdar et al. (2002) reported a similar response of sweet potato to K fertilizers dose in Alfisol, where the branches and leaves increased by increasing the rate of K2O fertilizers doses.

Tuber yield

According to the response regressions (Figure 2a and Table 4), the total tuber weight increased by increasing the dose of K fertilizers up to 125 kg K_2O ha^{-1}, and thereafter decreased where the K dose was at a luxurious consumption. The luxurious consumption dose of K fertilizers reduced starch content in tubers by 1.3 – 2.2%, and dry matter by 0.9-2.4% (Bhattarai and Swarnima, 2016). The K nutrient was needed for the high production. There was a positive correlation between soil available K and fresh weight of tubers (Singh et al., 2017; Anda et al., 2018). Bhattarai and Swarnima (2016) stated that K application plays an important role in increasing the yield of potato tubers which is either due to the increasing the number of tubers per plant or formation of large-sized tubers or both by improving in the accumulation of carbohydrate. A similar effect to the potato occurred in the sweet potato which were indicated by tuber weight and tuber diameter. From Figure 2a the dose of 125 kg K_2O ha^{-1} resulted in the highest tuber weight (357.4 g plant^{-1}, increased 179.5% compared to the control of 127.9 g plant^{-1}) and the biggest tuber with a diameter of 7.61 cm. This study also found the highly significant positive correlation among the variables of the tuber yield of weight/plant, marketable tuber/plant and tuber diameter (Table 5). Phusphalatha et al. (2017) recorded the highest sweet potato tuber diameter and fresh tuber weight per plant i.e. 6.24 cm and 451.49 g, respectively, by applying 100 kg K_2O ha^{-1} along with 125 kg N ha^{-1}.

To suport tuber yield, enough potassium supply improves the primary processes of photosynthesis by the increasing number of branches and leaves, and fresh weight of aboveground biomass. There were significant correlations between the source capacity as shown by those three variables and the tuber yield (Table 5). The potassium regulates the balance between assimilation and respiration to increase net assimilation for vigorous growth and formation of reserve assimilates (Byju and George, 2005).

Weevil infestation rate

Figure 3 shows a weevil infested sweet potato tuber. The number of infested tubers decreased with the increase of K dose (Figure 4). Based on the level of the highest tuber yield of the dose of 125 kg K_2O ha^{-1} resulted in reducing weevil infested tuber as much as 61.6 % (from 6.46, at the control dose to 2.37 tuber plant^{-1}). The percentage of weevil infested decreased along with the increase of K dose up to 125 kg K_2O ha^{-1}. There was a higly significant negative correlation (r = -0.8278) between the weevil infested rate and the increase of marketable tubers (Table 5). From Figure 2b, at the dose of 125 kg K_2O the maketable tubers increased as much as 8.75 times (from 0.35, at the control dose to 3.10 tubers plant^{-1}). Physical attributes such as skin thickness influenced sweet potato weevil infestation (Teli and Salunkhe, 1996). Klipcan et al. (2020) reported that K fertilization improves plant vigor and skin quality of sweet potato. In control plants, the skin of tubers was thin, consisting of 2–3 phellem cell layers. The skin morphology of sweet potato was modified by applying K fertilizers. The applying of 350 kg of KCl ha^{-1} increased the tubers skin thickness by adding one phellem layer enlarging size of the cells. The increase of skin thickness could correlate to a defense of sweet potato tubers from weevil infestation. Barreto et al. (2021) reported that the improvement of fruit quality of peach was occurred by applying 160 kg K_2O ha^{-1}.

Liao et al. (2020) reported that wound by sweet potato weevil attack induces jasmonic acid, salicylic acid, and abscisic acid (ABA) as phytohormones that regulate expression levels of genes involved in the chlorogenic acid formation, a natural anti-weevil metabolite as a response to insect attack. Formerly, Al-Amery and Khalaf (2017) showed that in an in vitro culture of potato, there was an interaction effect of jasmonic acid and potassium. Adding KNO_3 concentration by 1.5 times from recommended in MS medium combined with jasmonic acid at 1 mg L^{-1} resulted in a higher number microtubers, tuber diameter, fresh weight, dry weight percentage, and starch percentage than 0.5, 1.0, and 2.0 times. Potassium carbonate (K_2CO_3) is needed as a base catalyst in the synthesis of salicylic acid (Yamaguchi and Iijima, 2018). Wind et al. (2004) reported that ABA strongly lowered the potassium content within the cambial zone and reduced cambial activity so that enough supply of potassium is needed for improving plant growth. The result of the research related to these phytohormones metabolism which induces chlorogenic acid formation, indicating that it could be contributing to understanding that potassium in the right dose plays an important role in developing a control method to the sweet potato weevil infestation, with the study

Table 1. The soil chemical characteristics in the experimental site.

Soil properties	Value	Unit	Status
pH H2O	5.13	-	Acid
pH KCl	4.29	-	Acid
C-Organik	2.03	%	Moderate
P-Tersedia	8.35	Ppm P2O5	Low
N-Total	0.29	%	Moderate
K-dd	0.59	cmol K kg^{-1}	High
Mg-dd	1.67	cmol Mg kg^{-1}	Moderate
Ca-dd	2.90	cmol Ca kg^{-1}	Low
Na-dd	0.16	cmol Na kg^{-1}	Low
Al-dd	0.11	cmol Al kg^{-1}	-
H-dd	0.57	cmol H kg^{-1}	-
KTK	16.65	cmol kg^{-1}	Moderate

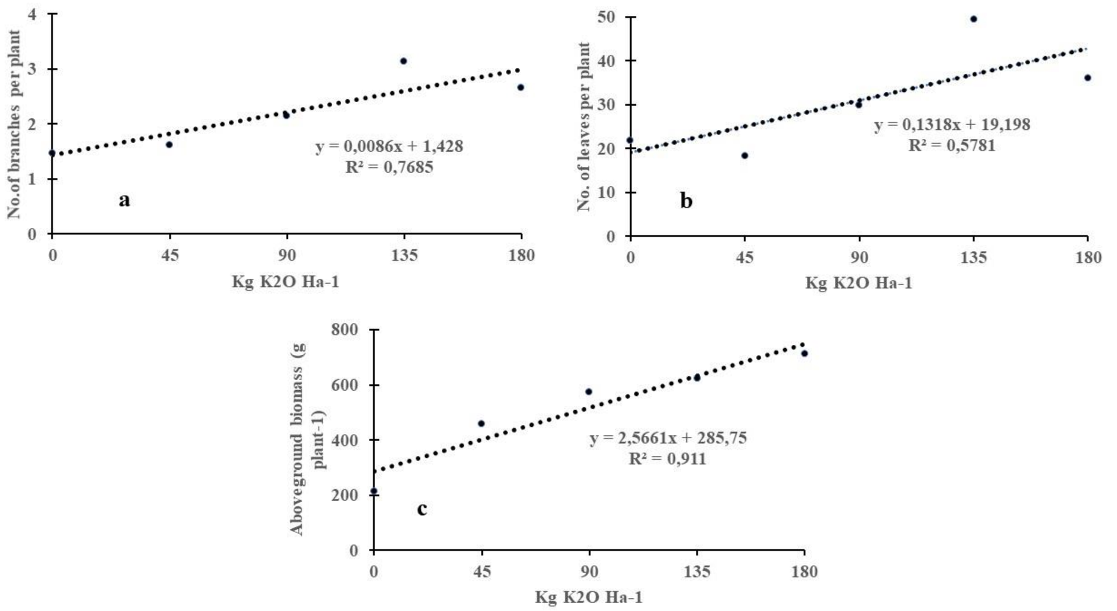

Fig 1. Response of number of branches (a), number of leaves (b), and weight of aboveground fresh biomass (c) to the rate of K2O fertilizers dose.

Table 2. Climate attributes during the experiment in the year 2020.

Month	Rainfall (mm)	Temperature (°C)	Relative humidity (%)	Sunshine (hours)
January	345	26.3	88.0	4.2
February	517	25.7	89.0	2.6
March	503	26.2	86.0	4.8
April	488	26.7	85.2	5.9
May	306	26.9	84.2	5.5
June	248	26.6	83.0	6.4
Average	401.2	26.4	85.9	4.9

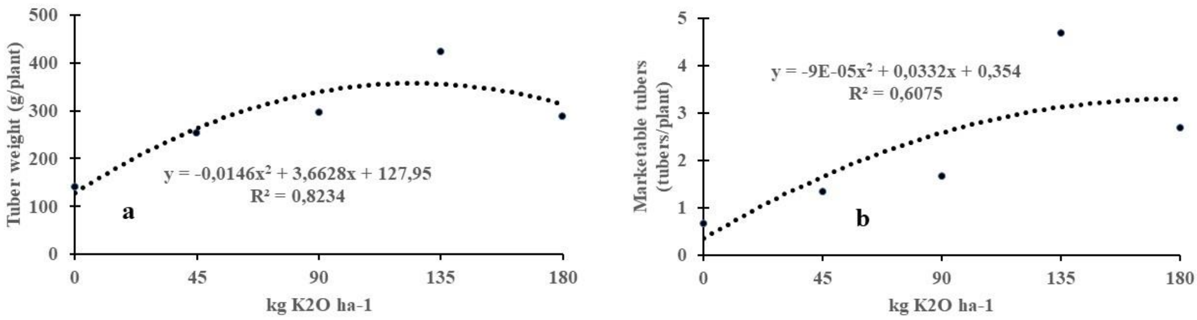

Fig 2. Response of tuber weight (a) and marketable tuber (b) to the rate of K2O fertilizers dose.

Table 3. Analysis of ortogonal polynomial and regressions of responses of growth variables to the rate of K fertilizer doses on sweet potato culture.

K2O rate (kg ha^{-1})	No.of Branches (branches plant^{-1})	No.of Leaves (leaves plant^{-1})	Fresh weight of aboveground biomass (g plant^{-1})
0	1.47c	21.79b	215.6b
45	1.62c	18.35b	459.81ab
90	2.14bc	29.85ab	574.00a
135	3.14a	49.39a	622.41a
180	2.65ab	35.93ab	711.67a
Pr>F	0,0128	0,0352	0,0728
Response	L*	L*	L^
Coef.of Variance	9,11	15,9	20,14
R^2	0,7685	0,5781	0,911

Notes: Means in the same column followed by the same letter are not significantly different at DMRT 5%. * significant at 0.05 level, ^ significant at 0.10 level

Table 4. Analysis of ortogonal polynomial and regressions of responses of tuber yield to the rate of K fertilizer doses on sweet potato culture.

K2O rate (kg ha^{-1})	Tuber weight (g plant^{-1})	Tuber diameter (cm)	Weevil infestation (tuber plant^{-1})	Marketable tuber (tuber plant^{-1})
0	140.20b	5,29	5.33a	0.67c
45	252.83ab	6,08	6.00a	1.33bc
90	296.68a	6,93	5.00ab	1.67bc
135	423.00a	7,81	0.67c	4.67a
180	287.17a	6,49	3.33bc	2.67b
Pr>F	0,0379	0,2941	0,0042	0,0018
Response	K*	ns	L**	K**
Coef.of Variance	15,83	9,93	17,76	14,73
R^2	0,8234	0,8362	0,7703	0,6075

Notes: Means in the same column followed by the same letter are not significantly different at DMRT 5%. ** = significant at 0.01 level, * = significant at 0.05%, ns = not significant

Fig 3. Sweet potato tuber infested by *C. formicarius.*

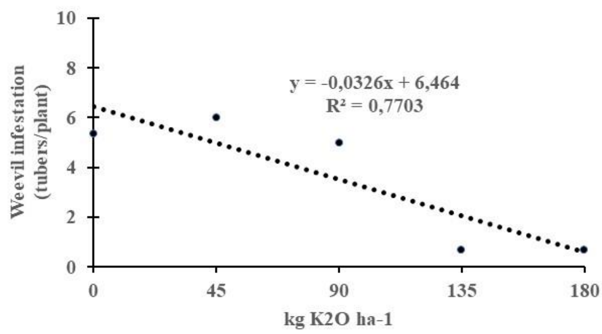

Fig 4. Response of weevil infestation to the rate of K2O fertilizers dose.

Table 5. Analysis of correlation among variables of plant growth, yield components and weevil infested level of sweet potato plant.

Variables	No. of leaves (leaves plant-1)	Weight of aboveground fresh biomass (g plant-1)	Weevil infestation (tuber plant-1)	Marketable tuber (tuber plant-1)	Tuber diameter (cm)	Tuber weight (g plant-1)
No. of branches (branche plant-1)	0.6586**	0.5277*	-0.7115**	0.7467**	0.3877ns	0.6193*
No. of leaves (leaves plant-1)		0.5714*	-0.7490**	0.6725**	0.4265ns	0.5758*
Weight of aboveground fresh biomass (g plant-1)			-0.4504ns	0.3741ns	0.2582ns	0.5510*
Weevil infestation (tuber plant-1)				-0.8278**	-0.4379ns	-0.6204*
Marketable tuber (tuber plant-1)					0.6264*	0.7434**
Tuber diameter (cm)						0.7884**

Note ** = significant at 0.01 level, * = significant at 0.05%, ns = not significant.

related to skin thickness of tuber (Klipcan et al., 2020) and the study of physiological approach related to the production of chlorogenic acid, anti-weevil metabolite (Al-Amery and Khalaf, 2017)

Materials and Methods

Soil and climate in the experimental site

A Field experiment was conducted in Latosol soil Darmaga Experimental Station, IPB University, Bogor, West Java, Indonesia located at 6°32'41" – 6°33'58" S/106°42'47" – 106°44'07"E and an altitude of 201 m. The soil properties were low pH (5.13), moderate soil organic carbon (2.03%), moderate N-total (0.29%), low available P (8.35 ppm P_2O_5), and high exchangeable K (0.59 cmol K kg^{-1}) (Table 1). The climate during the experiment was rainy seasons with an average rainfall of 401.1 mm $month^{-1}$, a temperature of 26.4 °C, relative humidity of 85.9%, and sunshine of 4.9 hours day^{-1} (Table 2). The rainfall and temperature were higher than environment suitability for sweet potato, which is in the range of rainfall 96 – 199 mm $month^{-1}$ and of temperature 21 – 22 °C (Anda et al., 2018). The warm temperature was suitable for sweet potato weevil attack (Liao et al., 2020).

Potassium treatment

Sweet potato local variety of Ase Kapas, with skin and fleshy white root was planted in January-July 2018. Five levels of K fertilizers doses of 0, 45, 90, 135, and 180 kg K_2O ha^{-1} were applied. A randomized block design experiment with 4 replications was used so that there were 20 experimental plots. Each experimental plot (4 m × 2 m) was prepared by plowing and harrowing, then it was formed to be 4 ridges with 2 m length. The stem cuttings of sweet potato with 30 cm length (Dewi et al., 2020) were planted on the center of the ridge with 0.20 m spacing. Before planting, the base of the stem cutting was submerged in Agrept and Dithane solution to sterilize (2 g L^{-1} and 2 mLL^{-1}) for 5 minutes. Fertilizing was conducted with the band placement method along with the plant row. Besides the K fertilizers dose, the plant was fertilized with 90 kg N ha^{-1} and 36 kg P_2O_5 ha^{-1}. All doses of P, 1/3 dose of N, and 1/3 dose of K were applied at 1 week after planting (WAP), and the rest were applied at 7 WAP. Weed was manually controlled. The land for the experiment was planted by cassava before so that it was assumed that the weevil population among the experimental plot was uniform. However, the population was not counted because of the difficulty to found *C. formicarius* at the early planting of sweet potato.

Data collecting and statistical analysis

Growth variables of sweet potato consisted of the number of branches and leaves was counted at 3 WAP, and aboveground fresh biomass was observed at harvest (20 WAP). Tuber number, tuber weight, tuber diameter, and weevil infested tuber were observed at harvest. Infested tuber by weevil was determined by visual observations and then counted.

The effect of K fertilizers doses treatment on the growth, tuber yield, and weevil infested tuber of sweet potato was determined using Analysis of Variance (Larson, 2008), and the analysis of simple correlation among the variables were also conducted. To determine the mathematical regression responses of the above variables to the K fertilizers doses, the analysis of polynomial orthogonal (Hubert, 1973) was conducted.

Conclusion

The highest tuber yield of sweet potato was achieved with high available K (0.59 cmol K kg^{-1}) by applying 125 kg K_2O ha^{-1}, the tuber yield increased 179.5% (357.4 g $plant^{-1}$, compared to the control of 127.9 g $plant^{-1}$) in the rainy season on Latosol soil. At the above mentioned dose of K fertilizers, the weevil infestation was reduced as much as 61.6 % (from 6.46, at the control dose to 2.37 tuber $plant^{-1}$) and marketable tubers increased as much as 8.75 times. This result could be the first understanding for further research in studying the role of K fertilizers for sweet potato weevil control using a culture technique approach.

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