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Relationships between potassium uptakes and yield performances of sweet corn grown under organic production system

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Abstract Production of sweet corn under organic production system was applied both solid and liquid organic fertilizer. Such production system might alter potassium availability to yield performances of sweet corn. The relationship between potassium uptakes and yields of sweet corn were determined. Twenty sweet corn varieties were grown under organic environment where soil was fertilized with 30 tons ha^{-1} of cattle-based vermicompost. Each plant was applied with thitonia-enriched liquid organic fertilizer of 50, 100, 200, 300 ml at 14, 21, 28 and 35 days of planting. Yield performances were recorded leaf potassium content, green biomass per plant, weight of husked ear, and weight of unhusked ear, sweet corn yield per plot and days to harvesting. Potassium uptakes by plants were calculated as ratio of plant potassium content and shoot dry weight per plant. Results indicated that potassium uptakes by sweet corn significantly increased shoot dry weight per plant (r=0.932), weight of husked ear (r=0.635) and sweet corn yield per plot (r=0.856). However, potassium uptakes by sweet corn did not significantly increase leaf potassium content (r=0.539) and weight of unhusked ear (r=0.515). In addition, potassium uptakes by sweet corn did not significantly decrease days to harvesting (r=0.130).

Keywords: Organic Production Systems; Potassium Uptakes; Sweet Corn Yields; Liquid Organic Fertilizer

Introduction

Production of vegetable in a closed agriculture production systems is a practice of organic vegetables production. Demands for organic sweet corn are steadily increasing due to increase quality of life of many consumers. Application of organic fertilizers in organic sweet corn production system aims to provide favorable growing environment for crop growth and development

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by modifying soil physic and chemistry (Ibrahim and Fadni, 2013) as well as soil biology (Lazcano *et al*., 2012). Such fertilizing potentially alters nutrient availability for sweet corn, including potassium. Potassium uptakes in organically grown sweet corn are very important for providing estimates amount of potassium must be applied to maintain the quality of crop performances and land resource sustainability.

Nevertheless, Hochmuth and Hanlon (2016) concluded that most fertilization research for sweet corn has widely been done with nitrogen and very little research with phosphor and potassium fertilization. However, there has been increasing number of research on sweet corn fertilization that focused on phosphor and potassium. Darman (2008), for example, concluded that the addition of compost extract could increase soil pH, total available phosphor, phosphorous uptakes and plant dry weight. In addition, Muktamar *et al.* (2016) conducted a research to evaluate the response of three sweet corn genotypes to organic fertilizer and concluded that sweet corn genotype significantly affected nitrogen uptake, but not phosphorus and potassium uptakes. Previously, Yusuff *et al*. (2007) evaluated the effects of compost, nitrogen and potassium fertilizer on nitrogen and potassium uptakes as well as yield of sweet corn grown on acid soil and concluded that nitrogen and potassium fertilization had significant effect on nitrogen and potassium uptakes in stem, but not in leaves of sweet corn.

Potassium plays important roles in increasing disease resistance, strengthening cell walls and improving the quality of many fruits. According to Sathiamoorthy and Jeyabaskaran (2001) potassium deficiency in organic farming may become a significant problem for successful crop production. Mikkelsen (2008) concluded that failure to maintain sufficient potassium in rhizosphere of organic crop production system brought about poor water use efficiency, greater pest problems, decreased harvest quality and eventually reduced yields. The roles of potassium are very crucial for nutrient balance in plant growth and development since potassium uptakes by plants also influenced nitrogen uptakes (Karamanos, 2013). Higher levels of nitrogen mean more potassium is required by plant to convert nitrogen into protein.

According to Marschner (2012), ion uptakes of particular nutrient by plant roots are affected by influx to the apoplasm, pH, metabolic activities, ion interactions in the rhizosphere, external concentrations and plant nutritional status. Successfulness of growing organic sweet corn requires consistent nutrient supply, includes potassium, to ensure sweet corn to have high growth and yields. Studies on potassium uptakes by organically grown sweet corns are limited on determination of total removal by sweet corn for determination the amount of potassium fertilizer applied for sweet corn (*e.g*. Rahman *et al*., 2008).

According to Mikkelsen (2007), potassium concentration in organic fertilizer (manures and composts) was highly variable, quite soluble and available for plant uptakes. Islam and Nahar (2012) reported that potassium uptakes by potato tubers from organically fertilized soil were higher than soil fertilized with inorganic fertilizer. However, information how potassium uptakes by sweet corn grown under organic production system relate to yield components are very limited.

The objective of this experiment was to determine the relationship between potassium uptakes and yield components of organically grown sweet corn.

Materials and methods

Experiments were conducted at Closed Agriculture Production System (CAPS) Research Station located in Air Duku Village, Municipality of Rejang Lebong, Bengkulu Province, Indonesia, at elevation of approximately 1.054 m above sea level (3°, 27', 30.38" South Latitude and 102°, 36', 51.33'' East Longitude).

Twenty sweet corn varieties were planted and arranged in randomized block design with three replicates. Land was cleaned, ploughed and harrowed before vermicompost at 30 ton ha^{-1} was uniformly applied into the soil. Experimental units of 2.8 m x 3.0 m soil beds were established and each plot was separated by 1 m within the block and each block was separated by 1.5 m away. In each plots, sweet corns were planted at 0.25 m x 0.70 m to make total of 30 sweet corn populations. Experimental site was previously used for organic vegetable production for four years.

Tithonia-enriched liquid organic fertilizer (LOF) was prepared as suggested by (Fahrurrozi *et al*., 2016). Each plant was fertilized with thitonia-enriched liquid organic fertilizer of 50, 100, 200, 300 ml at 14, 21, 28 and 35 days of after planting, respectively. During the experiment, weeds were removed from the experimental plots at 25 and 45 days after planting. All sweet corns were sprayed with organic insecticides contained *Corynebacterium* sp. as necessary.

Soil samples from top soil (0-20 cm in depth) were compositely taken before planting to determine the moisture content, pH, C-organic, N total, P_2O_5 and K. Laboratory analysis revealed that soil of experimental site was characterized by pH of 4.83, field capacity of 9.57%, organ total of 0.19%, organic C of 2.05%, P_2O_5 of 5.54 ppm and K of 0.27 me/100g. Plant potassium contents (%) were determined by using by wet destructive method. Leaf samples for potassium content analysis were taken from fully developed leaves, typically the third or the fourth leaf of upper most leaves. Determinations of weight of husked ears (g), weight of unhusked ears (g) and green mass per plant (g) were determined by taking the average weight of five sample plants in each plot. Weight of husked ears and weight of unhusked ears were determined in fresh weight basis, whereas shoor dry weight per plant was calculated by weighing after the shoots were dried and put in oven for 48 hours with 65 to 70 ^{o}C in temperature. Sweet corn yields per plot were expressed as a total weight of husked ears number of sweet corn per plot (g). Days to harvesting (days) were expressed as the number of days for sweet corn in each plot to be ready for harvesting, which was characterized by the cobs were fully developed, had dark brown hair and when the kernels were pressed, it produced milky water. Sweet corn's potassium uptakes were calculated as = PPC/100 SDW, where PPC is plant potassium content (%) and SDW is shoot dry weight per plant (g).

Relationships between sweet corn uptakes with plant potassium content, weight of husked ears, weight of unhusked ears, shoot dry weight per plant, yields per plot and days to harvesting were determined by using Prog Reg SAS ($P > 0.05$).

Results

Results indicated that potassium uptakes by sweet corn significantly increased shoot dry weight per plant, weight of husked and sweet corn yield per plot. However, potassium uptakes by sweet corn did not significantly increase leaf potassium content and weight of unhusked ear. In addition, potassium uptakes by sweet corn did not significantly decrease days to harvesting. Relationship between potassium uptakes by sweet corn and shoot dry weight per plant was significantly correlated (r=0.932) with quadratic equation of $Y = (-22.19) + 104.145x – 31.237x^2$ (Figure 1 A). Relationship between potassium uptakes by sweet corn and weight of husked ear was significantly correlated (r=0.656) with linear equation of $Y=84.824 + 221.662x$ (Figure 1 B). Relationship between potassium uptakes and sweet corn yield per plot was significantly correlated (r=0.828) with quadratic equation of $Y = (-2.073) + 9.7374x – 3.591x^2$ (Figure 1 C).

However, potassium uptakes by sweet corn did not significantly increase leaf potassium (r=0.539) with linear equation of $Y= 2.198 – 0.588x$ (Figure 1 D). Potassium uptakes by sweet corn also did not significantly increase of unhusked ear (r=0.515) with linear equation of $Y=101.562 + 105.923x$, (Figure 1 E). In addition, potassium uptakes by sweet corn did not significantly decrease days to harvesting (r=0.130) with linear equation of Y=90.974 – 4.33x (Figure 1 F).

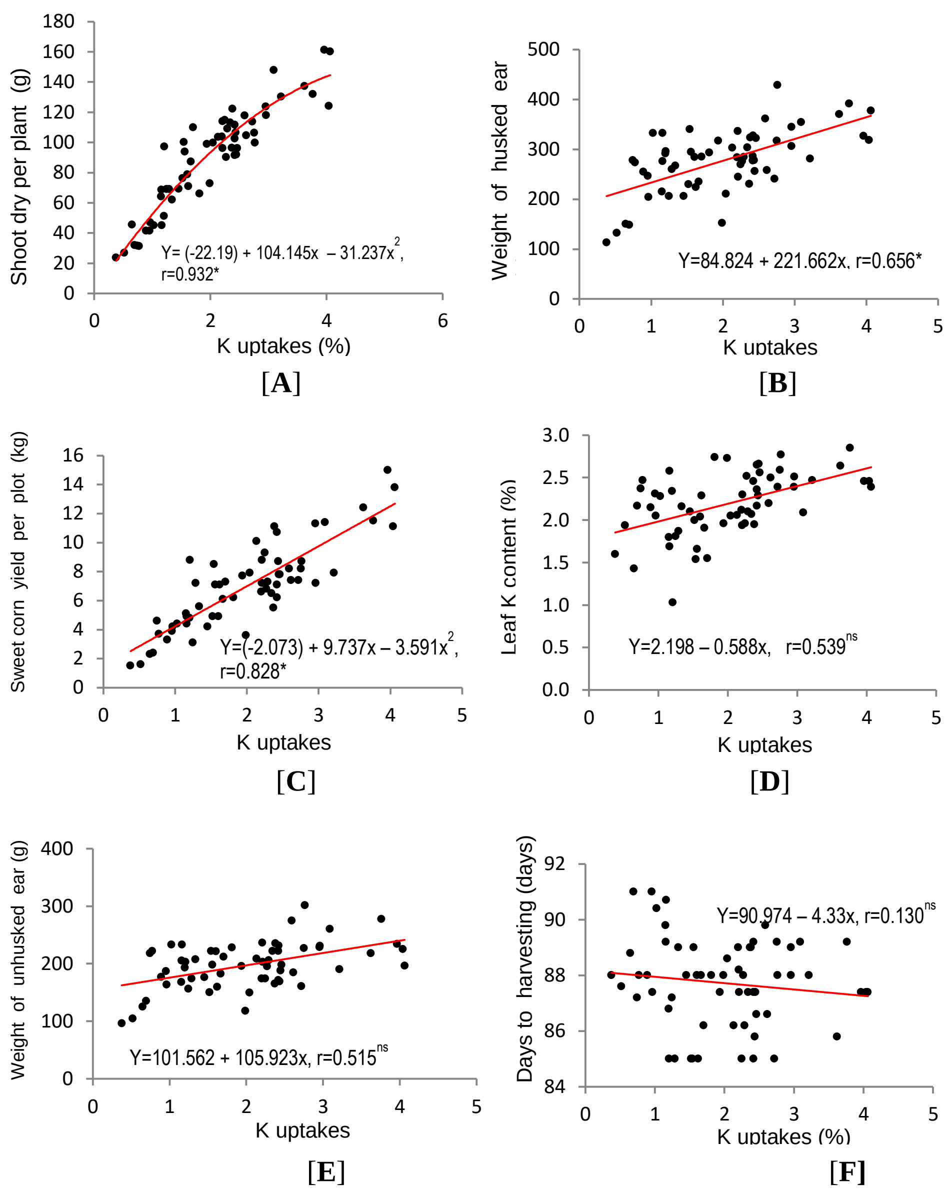

Figure 1. Relationship between K uptakes by sweet corn with green biomass per plant [A], weight of husked ear [B], sweet corn yield per plot [C], leaf potassium content [D], weight of unhusked ear [E] and days to flowering [F]

Discussion

Dry weight accumulation of sweet corn reflects its growth responses to particular environment conditions. Among many factors that might affect sweet corn growth and development, potassium is one of the essential nutrients required by this crop (Morgan and Connolly, 2013). Results from this experiment suggested that sweet corn growth was significantly influenced by the potassium uptake by plants (r=0.932) with quadratic relationship, $Y=(-22.19)+104.145x–31.237x^2$ (Figure 1 A). This implied that 86.86% dry weight of sweet corn was determined by potassium uptakes by plants. However, increased of potassium uptakes will not always bring about increased of sweet corn dry matter. The optimum potassium uptake by sweet corn to produce dry matter was 1.67 %.

Athough potassium does not form any vital organic compound in plants, the presence of potassium is essential for plant growth and development through its effects on enzyme activities (Uchida, 2000). According to Morgan and Connolly (2013), potassium is the most abundant cation within plant cells and functions to balance the charges of cellular anions, enzyme activation, control of stomatal opening/closing and serving as an osmoticum for cellular growth which eventually increased dry matter production. It is understood that the relationships between potassium uptakes and dry matter production was not linear, since number of plant cells is genetically controlled. Research conducted by Swetha *et al.* (2017), concluded that the application of potassium increased dry matter weight of *Zea mays* var. Everta. Similarly, Kaya *et al*., (2009) and Iqbal *et al*. (2015) reported that application of potassium was found to increase the shoot dry weight of maize which may be due to selective and adequate potassium uptake in plant tissue.

Potassium uptakes by sweet corns significantly influenced weight of husked ear and sweet corn yields per plot. Relationship between potassium uptakes by sweet corn and weight of husked ear was significantly correlated (r=0.656) with linear equation of Y=84.824+221.662x (Figure 1 B). This suggested that 43.03% increased of husked corn ears was determined by the potassium uptakes by sweet corn. In addition, there was a significant effect of potassium uptakes by sweet corn on sweet corn yield per plot (r=0.828) with quadratic relationship of $Y=(-2.073)+9.737x–3.591x^2$ (Figure 1 C). In other words, 68.56% of sweet corn yield per plot was controlled by potassium uptakes by plants. This relationship was well explained as the relationship between potassium uptakes by sweet corn and weight of husked ears of sweet corn since sweet corn yield per plot is a function of total weight of husked ear from individual sweet corn in each plot. Increased of sweet corn yields was presumably due to roles of potassium in plant metabolism as enzyme activator. According to Potash and Potassium Institute (1998), potassium gets involved in more than 60 types of growth enzymes. Results from this experiment complied with those of conducted by (Potash and Potassium Institute, 1998; Zeng *et al*., 1999; Pradipta *et al.*, 2014). However, this finding suggested that effect of potassium to total sweet yield was quadratically correlated. Increasing potassium uptakes by sweet corn will not be always followed by sweet corn yield per plot. Result suggested that optimum potassium uptake by sweet corn to have the highest production is 1.36 %.

Although there was a linear relationship between potassium uptake by sweet corn with leaf potassium content (Y=2.198–0.588x), potassium uptakes by sweet corn did not significantly increase leaf potassium content (r=0.539) (Figure 1 D). This implied that sweet corn leaves did not dominate potassium uptakes and potassium might be equally distributed by sweet corn to other plant organs, such as stem, cob ears and roots. Such distributed potassium was later used up by sweet corn metabolisms. Research conducted by Khan *et al*. (2018) revealed that potassium uptakes by sweet corn were distributed into grain and stover. According to Canatoy (2018), potassium uptake by sweet corn leaves was affected by nutrient availability, including potassium, in the rhizosphere of sweet corn.

Unlike the relationship between potassium uptakes by sweet corn with weight of husked ears, potassium uptakes by sweet corn did not significantly increase unhusked ear (r=0.515) with linear equation of Y=101.562+105.923x, (Figure 1 E). These results, however, were not in line with those reported by Praddipta *et al*. (2014) where potassium fertilizer significantly affect both husked and unhusked ears of sweet corn. Less effect (only 26.52%) of potassium uptakes by plants on unhusked ears of sweet corn might have been due to genetic control of sweet corn on cobs/ears characteristic. According to Saleh *et al.*, 2002; Kashiani *et al*., 2010), ear yield represented a quantitative trait and acted dependently with other related traits. According to Chozin *et al*. (2017), ear yields were highly correlated with length and diameter of sweet corn ears as well as kernel row number. Research conducted by Khan *et al*. (2018) revealed that the number of potassium uptakes by grain of sweet corn was ony about 50% compared to uptakes by stover.

Although the effect of potassium on days to harvesting tended to decrease with a linear relationship (Y=90.974–4.330x, Figure 6), potassium uptakes by sweet corn did not significantly decrease days to harvesting (r=0.130). Report released by Potash and Phosphat Institute (1998) summarized that potassium might increase crop yield by speeding corn silking, but potassium delayed corn maturity. This delay benefitted plants to have more time for grain filling and eventually increased crop yields. The ways of potassium influence crop maturity might be very complex, since this nutrient mainly involved in many enzymatic processes as an activator. However, this finding suggested that additional potassium uptakes might shorten days to flowering, though no other reports have confirmed. Harvesting is a function accumulated heat received by plant and genetically control. With respect to nutrient availability, days to harvesting might be mainly accelerated by the number of phosphorous received by plants since this nutrient induces early growth and development (Marschner, 2012).

In conclusions, under organic growing environment, potassium uptakes by sweet corn significantly increased dry weight per plant, weight of husked ear and sweet corn yield per plot, but not leaf potassium content and weight of unhusked ear. In addition, potassium uptakes by sweet corn did not significantly decrease days to harvesting.

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