Effect of different levels of potassium on the growth and yield of sugarcane ratoon in inceptisols

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Abstract. The production of sugarcane in Indonesia has been decreased from a year to another, because its growth is less than optimal due to potassium content in the soil is low. Potassium is an activator of several enzymes of generative growth and synthesis of sucrose in sugarcane, therefore, adding KCl fertilizer is expected to increase the growth and productivity of sugarcane. The research aimed to determine the effect of potassium fertilizer on the growth and productivity of sugarcane. Research has been conducted from September 2015 until July 2016 in Karangploso Experimental Station, Malang. The study used PSJK 922 (a middle ripening variety) and arranged in a randomized block design (RBD) with 4 replications. The treatment consisted of five doses of K2O fertilizer, i.e.: 0, 60, 120, 180, and 240 kg/ha. The results showed that increasing the potassium fertilizer dose from 0 kg K2O/ha to 240 kg K2O/ha did not significantly affect plant height (average 3.36 m) and number of the stalk (average of 13 stalk/m). However, 180 kg K2O/ha increased sugarcane stalk diameter from 28.20 mm to 30.53 mm, sugarcane stalk weight increased from 0.67 kg/m to 0.78 kg/m, so sugarcane yield also increased from 109.58 to 138.18 ton/ha.

Introduction

Sugarcane is a type of grass plant which contains high sucrose in its stalk [1]. The high sucrose in sugarcane makes it become a strategic main commodity. Several food industries used sugarcane as one of their main ingredients. However, the high demand of sugar is not followed with high production. The production of sugarcane in Indonesia experienced a decrease from a year to another. In 2012, the production of sugarcane was 2,592.56 tons and declined into 2,553.50 tons in 2013 [3]. The decrease of sugarcane productivity due to sugarcane was grown in low nutrients soil [4]. One of the nutrients required for sugarcane to grow in the growing phase is Potassium (K).

According to [5], K has a function as an activator of several growth enzymes of sugarcane. One of them is an essential enzyme activator in the metabolism reaction and enzyme involved in the synthesis of starch and protein [6,7]. Within one ton of sugarcane harvest, there are 1.95 kg N; 0.30 – 0.82 kg P2O5 and 1.17 – 6.0 K2O removed the soil [8, 9]. Therefore, during sugarcane growth, it is required quite high N, P, and K so when after harvesting, the nutrients in soil remain sustained and are capable of supporting sugarcane growth in the next season. According to [10], in order to reach productivity of 100 ton/ha, sugarcane requires 200 kg N; 85 kg P2O5 and 420 kg K2O per hectare. Therefore, sufficient amount of fertilizer should be given to the soil with proper nutrient management.

Considering the fact that potassium is important for the sugarcane growth, and the dose of K fertilizer is an important part that must be acknowledged, then there’s a need for studies regarding the effect of...
K fertilizer dose on the sugarcane growth and productivity. The objective of this research was to determine the effect of potassium fertilization dose on sugarcane growth and productivity.

Materials and Methods

The research has been conducted from September 2015 until July 2016 at Karangploso Experimental Station, Malang. The planting material used was first ratoon cane (RC-1) of PSJK 922 (a middle ripening variety). The treatment of K fertilizer dose presented in Table 1.

| No | Code | A dose of K fertilizer (K₂O/ha) |
|----|------|---------------------------------|
| 1  | K1   | 0                               |
| 2  | K2   | 60                              |
| 3  | K3   | 120                             |
| 4  | K4   | 160                             |
| 5  | K5   | 220                             |

The research was arranged in a Randomized Block Design with 4 replicates. The experimental unit consisted of 6 rows and 10 m long. As a basic fertilizer, N was given twice at a rate of 60 and 120 kg/ha in form of ZA, 108 kg P₂O₅/ha in form of SP-36 and 3 ton/ha organic fertilizer. The harvest is done to the ratoon cane plants aged 12 months after being ratooned (MAR).

The observation of growth parameters included: 1) Plant height, measured from the soil surface up to the first leaf joint, 2). Number of stalks, counted and sampled when stalks length above 1.5 m and 3). Diameter of the stalk, measured from the middle of the sample stalk. Production parameter included: 1) weight of stalk, measured by weighing 10 sampled stalks, length of stalk, harvested from the sample section and 2). Brix of middle stalk was measured using refractometer. Observation from each treatment was done along 10 m and sampled within 4 rows (second, third, fourth, and fifth row). The data collected were analyzed statistically using ANOVA. The difference then further tested using HSD test with 5% level. In addition, the availability of soil K before planting and after harvesting of ratoon-1, also K-leaves was measured.

Results and Discussion

The analysis result of the soil sample of the experimental site was considered as an infertile soil characterized by low to very low rate of N, P, and K yet has intermediate organic material reserves (Table 2).

| No | Type of Analysis | Unit  | Result | Criteria |
|----|------------------|-------|--------|----------|
| 1  | pH 1:1 H₂O       |       | 6.50   | Rather Acid |
| 2  | pH 1:1 KCl       |       | 5.80   |          |
| 3  | C. Organic       | %     | 2.01   | Intermediate |
| 4  | N. total         | %     | 0.10   | Low |
| 5  | C/N              |       | 20.10  |          |
| 6  | P. Bray          | mg kg⁻¹ | 3.78  | Very Low |
| 7  | K                | me/100 g | 0.15 | Low |
| 8  | Na               | me/100 g | 0.19 | Low |
| 9  | Ca               | me/100 g | 11.22 | High |
The Effect of Potassium Fertilization Dose on Sugarcane Growth Components

There was no significant difference among treatments on the number of stalk, but the highest number of stalks per meter of 11 month old sugarcane was obtained when potassium fertilizer (K₂O) was applied at the rate of 180 kg/ha (13.73), and the lowest value was gained at the dose of 120 kg/ha (Table 3). The average number of stalks above 13 was considered high and could produce the expected sugarcane yield. In this study, K₂O did not give significant effect on number of stalk. Several factors affected number of sugarcane stalk [11].

The plant height was not affected by Potassium fertilizer (K₂O) doses (Table 4). Potassium has a role in the process of photosynthesis, protein synthesis, transformation, sugar and protein translocation process. K acts as a catalyst in the plant’s metabolism process and is found when there is a high energy transformation [12]. Furthermore, it is stated that its existence enables the formulation of sugar from the substance of simple carbohydrates and alter sugar into starch and other high molecular weight carbohydrates. Based on the overview above, giving Kalium a chance does not affect sugarcane growth. A similar result was obtained by [13, 8], that the K fertilization will determine the quality of sugarcane production instead of the growth components.

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The table below presents the effect of potassium fertilizer dose on the number of ratoon stalks.

**Table 3. The Effect of Potassium Fertilizer Dose on the Number of Ratoon Stalks**

| Dose of K₂O (kg/ha) fertilizer | Number of stalks per meter | Mean | CV (%) | HSD 5% |
|-------------------------------|---------------------------|------|--------|--------|
|                               | 8                        | 9    | 10     | 11     |
|                               | 0 | 14.33 | 13.38 | 13.13 | 13.13 |
|                               | 60 | 14.58 | 13.51 | 13.53 | 13.53 |
|                               | 120 | 13.62 | 13.69 | 12.80 | 12.80 |
|                               | 180 | 13.83 | 13.44 | 13.53 | 13.73 |
|                               | 240 | 14.03 | 13.68 | 13.79 | 13.59 |

HSD 5% ns²  ns  ns  ns

CV (%) 14.07  3.88  5.37  16.69

*Not significant
MAR= Month After Ratoon

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*²Soil Chemical Assessment according to the Center for Soil Research (2009)
Table 4. The Effect of Potassium Fertilizer Dose on the Plant Height of Ratoon Sugarcane

| Dose of K₂O (kg/ha) Fertilizer | Plant height (cm) | MAR | HSD 5% | CV (%) |
|-------------------------------|-------------------|-----|--------|--------|
|                               | 8                | 9   | 10     | 11     |
| 0                             | 288.20           | 306.08 a *) | 335.89 | 344.38 |
| 60                            | 297.75           | 331.58 b | 345.00 | 353.23 |
| 120                           | 293.93           | 329.75 b | 341.33 | 348.18 |
| 180                           | 296.75           | 325.63 b | 348.10 | 360.23 |
| 240                           | 292.60           | 332.63 b | 349.30 | 360.48 |

*) Numbers accompanied by the same letter in the same column are not significantly different by HSD test at 5% level.
**) Not significant
MAR= Month After Ratoon

The Effect of Potassium Fertilization Dose on Sugarcane Production Components

The components of sugarcane production were length of stalk, weight of stalk, and population of sugarcane before the harvest. The best results were achieved when sugarcane plants were fertilized with 180 K₂O kg/ha. All of the sugarcane production components, sugarcane yield and content reached the highest value, stalk length (363.05 cm), stalk weight (0.79 kg per m per stalk), stalk diameter (30.53mm), yield (138,18 ton/ha), and sugar content (17,16 ton/ha) (Table 5). Similar result was also obtained by [16], in which potassium affected sugarcane stalk diameter. Ahmed et al [14] reported that in Nigeria K fertilization positively interacted with variety. They recommended 90 kg K₂O/ha to get heaviest stalk weight (0.67 kg/m). Meanwhile, [15] stated that potassium fertilization is very essential nutrient and should be applied to get the expected sugarcane production. They also claimed that potassium support sugarcane plant facing stress during dry season.

Table 5. The Effect of K Fertilizer Dose on the Production Components, Sugarcane Yield and Sugar Content

| Dose of K₂O (kg/ha) Fertilizer | Stalk Length (cm) | Stalk weight per m (kg) | Parameter | Brix (%) | Sugarcane Yield (ton/ha) | Sugar Content (ton/ha) |
|-------------------------------|-------------------|-------------------------|-----------|----------|-------------------------|------------------------|
| 0                             | 337.23 a *)       | 0.67 a                  | Stalk diameter (mm) | 28.20 a | 11.19                    | 109.58 a               | 13.04                 |
| 60                            | 354.80 b          | 0.70 b                  |            | 28.64 a | 11.95                    | 119.25 b               | 14.25                 |
| 120                           | 350.48 ab         | 0.71 bc                 |            | 29.37 b | 12.08                    | 126.05 b               | 15.42                 |
| 180                           | 363.05 b          | 0.78 d                  |            | 30.53 c | 12.42                    | 138.18 c               | 17.16                 |
| 240                           | 350.23 ab         | 0.73 c                  |            | 29.40 b | 11.30                    | 133.73 c               | 15.11                 |

HSD 5% | ns**) | ns
CV (%) | 4.9 | 11.20 | 15.23 | 2.35 | 11.55 | 2.08
In contrast, without K$_2$O fertilizer application, sugarcane plants had the lowest production. According to [17], the increase of potassium fertilizer dose would increase sugarcane and sugar production in ratoon plant cane 1. However [18] found that application of 99.6 and 161.9 kg K$_2$O/ha in ratoon cane-1 in the Oxisols soil did not increase sugarcane production (87.0 and 87.5 ton/ha respectively). Whilst [16] reported that the addition of 168 kg K$_2$O/ha for 2 seasons of sugarcane cultivation (PC and RC-1) consistently gave the highest plant growth of PC (301 cm) and of RC-1 (301.9 cm).

Report of [19] showed that addition of 60 K$_2$O (equal to 100 kg KCl/ha) on Vertisols increased sugarcane production up to 71.14 tons/ha and 7.29% yield. The addition of 180 K$_2$O (equal to 500 kg KCl/ha) on Entisols increased sugarcane productivity up to 91.01 tons/ha and 8.54% yield. Whereas on Alfisol, the addition of 120 K$_2$O (equal to 200 kg KCl/ha) increased sugarcane productivity to 129.67 tons/ha and 7.88% yield.

Effect of Potassium Fertilization Dose on the Soil Chemicals in Inceptisols

Availability of K Soil

Application of potassium fertilizer significantly affected the availability of K in the soil (Table 6). The higher the dose of K$_2$O, the higher the availability of K in the soil. The highest value of the availability of K (0.88 me K/100 g) occurred 6 MAR in soil treated with 240 kg K$_2$O/ha, although dose of 180 kg K$_2$O /ha has provided adequate K nutrient for the plant to produce best sugarcane production.

Table 6. The effect of potassium fertilization dose on the availability K in the soil.

| Dose of K$_2$O (kg/ha) Fertilizer | Before planting RC-1 | 6 MAR |
|----------------------------------|----------------------|-------|
| 0                                | 0.11 a\(^1\)         | 0.24 a|
| 60                               | 0.13 ab              | 0.27 a|
| 120                              | 0.15 b               | 0.38 a|
| 180                              | 0.17 b               | 0.60 b|
| 240                              | 0.23 c               | 0.88 c|
| CV (%)                           | 3.40                 | 4.50  |

\(^1\) Numbers followed by the same letter in the same column are not significantly different by HSD test at 5% level; MAR= Month After Ratoon
The increasing of the availability of K in the soil was related to the soil CEC in which it will exchange cation in a form of components available for the plant. The high value of soil CEC lead high K availability in the soil because of the cation exchange activity with the plant’s root respiration [20].

1.1.1. The Value of K on Sugarcane Leaves
Potassium content in sugarcane leaf was significantly affected by the addition of K$_2$O in the soil. The highest level of K (2.42%) on 7 MAR sugarcane leaves occured when the plants were treated with 240 kg K$_2$O/ha. Potassium content in the sugarcane leaves increased constantly since along the growth of sugarcane, K will also be absorbed continuously above the normal need [21]. This result was different to the finding of [22].

| Dose of K$_2$O (kg/ha) Fertilizer | Age observation (MAR) |
|-----------------------------------|-----------------------|
|                                   | 5         | 6         | 7         |
| 0                                 | 1.64 a$^*$ | 1.70 a    | 1.80 a    |
| 60                                | 1.68 a    | 1.84 a    | 1.95 ab   |
| 120                               | 1.73 a    | 1.87 ab   | 1.99 ab   |
| 180                               | 1.88 b    | 2.07 c    | 2.14 b    |
| 240                               | 2.03 c    | 2.31 c    | 2.42 c    |
| CV (%)                            | 8.71      | 7.60      | 4.50      |

*) Numbers followed by the same letter in the same column are not significantly different by HSD test at 5% level; MAR= Month After Ratoon

Medina et al. [22] studied potassium distribution during sugarcane growth. The concentration of potassium in the roots, stalks, and leaves were higher in the initial growth of the plant and then decreased when the plant was mature.

Relationships Among Observation Parameters
Correlation and regression test between the sugarcane middle stalk diameter and sugarcane productivity was correlated positively with strong relationship ($r = +0.77$). Positive correlation means increased sugarcane diameter will be followed with the increased sugarcane productivity. $R^2 = 0.59$ shows that the size of the middle sugarcane stalk diameter influences the sugarcane productivity as much as 59% and the rest (41%) is influenced by other factors.
Figure 1. Relationship between middle stalk diameter and sugarcane productivity

The regression model between the sugarcane middle stalk diameter and productivity is $y = 11.032x - 227.72$. It means that each addition of unit of sugarcane middle stalk diameter will increase the productivity by 11.03%.

Correlation and regression test between the soil CEC and availability of K in the soil is correlated positively with strong relationship ($r = 0.89$) (Figure 2). Positve correlation means that the more increased the soil CEC is, the more increased the availability of K in the soil. According to [23], correlation between soil CEC and the availability of K in the soil was also positive. Figure 2 depicts the value of $R^2 = 0.79$ which means the soil CEC gives an influence as much as 79% on the availability of K in the soil and the rest is influenced by other factors. According to [24], the availability of K in soil is influenced by several factors, including soil CEC. The regression model between the soil CEC and availability of K in the soil is $y = 0.0065x - 0.0078$ which is interpreted as every addition of soil CEC units will increase the availability of K as much as 0.6%.

Correlation and regression test between the availability of K in the soil and the value of K in the leaves is correlated positively with strong relationship ($r = 0.87$) (Figure 3).
Figure 3. Relationship of the availability of K in the soil and value of K in the leaves

Positive correlation means the more increased the availability of K in the soil is, the more increased the value of K in sugarcane leaves will be. Figure 3 depicts the value of $R^2 = 0.75$ which means the availability of K in the soil influences as much as 75% on the value of K in the leaves. The regression model between the availability of K in the soil with the value of K in the leaves is $y = 3.3178x - 1.2767$ which is interpreted as every addition of units of the availability of K in the soil will increase the value of K in sugarcane leaves as much as 3.32%. According to [25], the increase in the availability of K in the soil due to the increase of soil CEC and will increase the value of K in the leaves. This is because there are more K$^+$ ions exchanged into the soil and available to be absorbed by plants as a result of an exchange with the plant respiration results.

Conclusion

For the cultivation of Ratoon cane 1 in Inceptisols soil, the increase of potassium fertilizer dose from 0 kg K$_2$O/ha to 240 kg K$_2$O/ha doesn’t increase the number of sugarcane stalks (an average of 13 stalk/m) and sugarcane height (an average 3.36 cm). However, increase the dose of fertilizer up to 180 kg K$_2$O/ha increased the diameter of the sugarcane stalk from 28.20 mm to 30.53 mm and weight of sugarcane stalk from 0.67 to 0.78 kg/m. The highest sugarcane productivity of 138.18 ton/ha and the highest sugar content of 17.16 tons/ha were achieved with the dose of 180 kg K$_2$O/ha.

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