Effect of salt stress on nutrients content in soil and leaves of three varieties sugarcane

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Abstract: The extension of the sugarcane cropping area in Indonesia is directed to saline soil, yet there is still limited information about the effect of salt stress on commercial varieties of sugarcane. A pot study was conducted at the Indonesian Sweetener and Fiber Crops Research Institute greenhouse in 2019. The objective was to investigate salinity influences on three varieties: sugarcane growth, soil nutrient content, and leaves. Treatments included three commercial sugarcane varieties (PS 881, PSJK 922, and BL) with five different watering salt concentrations (0, 2000, 4000, 6000, and 8000 ppm of NaCl solution added). Results showed that saline stress decreased the organic and available K of soil. Increasing NaCl concentration also reduced the content of N, K, and ratio K/Na of sugarcane leaves. The stalk diameter of sugarcane was also decreased under saline stress. Among the three tested sugarcane varieties, BL was the most susceptible to saline stress in relation to the most reduction in stalk diameter and ratio K/Na.

Keywords: saline soil, nutrients, tolerant variety

1. Introduction

Sugarcane in Indonesia is an important commodity and is used mainly as the raw material of sugar. As a sweetener ingredient, most of the sugar is consumed by the food and beverages industries. In 2017, the demand for sugar was 7,227 tons, and it increased in 2018 as much 7,522 tons. However, the national sugar supply is much lower than its demand. The average available domestic sugar is only 2,712 tons [1].

In order to supply the demand for national sugar, the government has imported raw sugar and expanded the cropping area of sugar cane. Imported raw sugar in 2017 was 4,549 tons, and it increased in 2018 as much 5,021 tons [1]. With an increasing population and growth of food industries, the amount of imported raw sugar seems likely to increase in the coming years. Enlarging the cropping area of sugarcane in arable land is also facing the problem because the arable land is mainly for other food crops, such as rice, corn, and soybeans. In 2018, areal cropping of sugar cane was 415,660 hectares, and total sugar production was 2.17 million tons.

An extension of the sugar cane cultivation area in Indonesia is directed to marginal land, including saline soil. The saline soils in Indonesia occupy the land with 12 million hectares or 6.20% of Indonesian land [2]. Soil is categorized as saline soil when it generally has the electrical conductivity (EC) of the saturation extract (ECe) in the root zone exceeds 4 dS/m (approximately 40 mM NaCl) at 25 °C and has exchangeable sodium of 15% [3]. The area and seriousness of salinity in agricultural land are predicted to increase due to inadequate drainage of irrigated land, rising water...
tables, global warming, land clearing, and accumulation of dissolved salts [4]. The high content of salt in soil has an adverse influence on the growth and yield of the most plant.

Accumulation of salt in agricultural soil is commonly done through fertilization and irrigation [3, 4]. Generally, the salts contain cations Na⁺, Ca²⁺ and Mg²⁺, and anions Cl⁻, SO₄²⁻ and HCO₃⁻ [3]. However, NaCl is considered the most toxic salt to plants [4]. The negative effect of Na⁺ is indicated by the ability to depress K⁺ absorption and to decrease K⁺ content in the leaf. K is an essential macronutrient that has a role in supporting the metabolism process of sugar cane. Therefore, depressing K⁺ absorption by Na⁺ will lower the yield and sucrose content of sugar cane.

Plant responses to saline varies differently from soil to soil and from salt type to salt type, and the plant is different among crop species and growth phases [5, 6]. For example, sugarcane is a glycophyte plant, which expresses stunted growth or zero growth due to salinity [7, 8]. The influences of salinity on sugarcane are indicated by reducing root growth, chlorophyll contents, and dry matter yield [9], decreasing plant height and number of stalks [10], hampering photosynthetic rate, transpiration rate, and dry biomass accumulation [11], and depressing stomata conductance and photo assimilate translocation from leaves to other plant tissues [14].

Some commercial sugarcane varieties cultivated in Indonesia are PS 881, PSJK 922, and BL. Their responses to salinity might be different due to their susceptibility to the salt toxic [12, 13]. The growth of sugarcane BL variety was depressed when it was watered with a concentration above 100 mM of NaCl [15]. However, information about the response of the Indonesian commercial sugarcane with regards to nutrient contents in soil and sugarcane leaves is still scanty. Thus, the objective of this study was to identify the effect of NaCl on nutrient content and the growth of sugarcane.

2. Materials and methods

2.1. Soil

Non-salinized clay soil (EC of 0.97 dS m⁻¹) collected from a surface layer (0-20 cm) in Malang Experimental Station of Indonesia Sweetener, and Fiber Crop Research Institute (ISFCRI) was used in this study. The soil was air-dried for ten days, sieved passing through a 2 mm mesh, and homogenized. As much as 30 kg of soil was transferred to each pot (30 cm in diameter and 38 cm in depth). The soils contain low organic matter (1 %), very low Nitrogen (0.07%), medium Phosphorus (12.41 mg kg⁻¹), and low Potassium (0.54 me 100g⁻¹).

The study was conducted in a greenhouse of ISFCRI at Malang, East Java, in 2019. The site has an altitude of 534 m above sea level and a temperature of 27-31°C.

2.2. Plants and treatments

Three commercial varieties of sugarcane (Saccharum officinarum L.), i.e. PS 881, PSJK 922, and BL were obtained from ISFCRI. Three stalk node buds (one eye piece) were planted in each pot. The sugarcane seeds were watered with tap water for each day until one week. After one week, watering of plant media was using NaCl solution. After two weeks of sugarcane growth, only one seedling was maintained to grow in each pot.

The treatments of the study were three sugarcane varieties (PS 881, PSJK 922, and BL) and five concentrations of NaCl solutions (0, 2000, 4000, 6000, and 8000 ppm). This study was arranged in Factorial Randomized Block Design with three replications.

NaCl solution was irrigated (as treatments concentration) into the pots in each week interval, and NaCl watering eased at 5 weeks after planting. After 5 weeks of NaCl watering, the soils EC recorded were 1.11, 4.30, 5.41, 6.39, and 7.08 dS m⁻¹ respectively for 0, 2000, 4000, 6000, and 8000 ppm NaCl solutions. Fertilizer with the rate of 12 g ZA and 4.5 g ZK was added twice in each pot, at one month and two months after planting, in each pot was added with the fertilizer of 12 g ZA and 4.5 g KCl, while 3 g SP36 per pot was added at one month after planting.
2.3. Parameters observation and data analysis

Observations were done on parameters of soil C-organic and available K contents, leaf N, K, and Na contents, sugarcane growth (plant height and number of tillers). Soil’s C-organic was analyzed using Walkley-Black Method. All parameters were observed 4 months after planting. In addition, leaf sample number three, which grows in the main stem, was collected for analysis (Figure 1).

All data collected were analyzed using ANOVA. The least significant difference test was used to compare the effect of each treatment. There was a significant effect of interaction between salt concentration and sugarcane varieties on all parameters observed, except its effect on the number of tillers. In general, an increasing salt concentration had a negative effect on soil chemical properties, nutrient content, and plant growth of three varieties of sugarcane.

![Figure 1. The third leaf sample for analyses](image)

3. Results and discussion

3.1. Soil chemical properties

Initially, the soil used as a sugar cane growing media has low soil organic content (1%). However, after the sugarcane had been planted for 4 months, there was a significant difference in soil organic content due to interaction treatment of NaCl concentration and sugarcane varieties. In the control treatment (0 ppm NaCl), the least soil’s C-organic content was found in soil grown with PS 881 variety (1.94 % C) which was a significant difference from those in soil grown with PSJK 992 and BL varieties (Table 1). As sugarcane biomass is a source of carbon (C) for soil through straw and root stalk decomposition [16], the difference of soil’s C-organic after 4 months of planting might be due to the difference in biomass production among the varieties. A previous study found that dry trash of biomass depended on sugarcane varieties [17].
The K/Na ratio was higher in

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Table 1. Effect of salt concentration on soil C-organic and available K at 4 months after planting.

| NaCl treatments (ppm) | Soil’s C-organic (%) | Soil’s K available (me 100 g⁻¹) |
|-----------------------|-----------------------|----------------------------------|
| PS 881                | PSJK 922              | BL                               |
| 0                     | 1.94 ef               | 2.03 fg                          | 2.07 g                        | 0.75 b | 0.77 b | 0.77 b |
| 2000                  | 1.93 e                | 2.02 fg                          | 1.91 de                       | 0.75 b | 0.77 b | 0.73 b |
| 4000                  | 1.84 cde              | 1.91 de                          | 1.75 bc                       | 0.74 b | 0.73 b | 0.68 b |
| 6000                  | 1.82 cd              | 1.78 c                           | 1.66 ab                       | 0.63 a | 0.62 a | 0.63 a |
| 8000                  | 1.77 c               | 1.77 c                           | 1.64 a                        | 0.62 a | 0.62 a | 0.63 a |

Numbers followed by the same letters in each row and column for each variable are not significantly different

Elevation NaCl concentration significantly decreased the content of soil organic C in soil media grown with the three varieties of sugarcane. Some researchers also reported that saline stress reduced the soil’s C-organic content [18–20]. Degradation of soil’s C-organic was attributed to decreasing organic matter decomposition as saline stress reduces soil microorganism activity [21,22]. Increasing salt concentration in watering solution had a significant influence on soil available K (Table 1). High salt concentration (6000 ppm) significantly decreased available K content in soil cultivated with three sugarcane varieties. Previously study also found that increasing salt concentration caused K content in soil to decrease [23].

3.2. Nutrient content of leaves

Interaction between NaCl concentration and sugarcane varieties had a significant effect on the N and K contents of the leaf. N and K leaf contents of the three sugarcane varieties were lowered by increasing salt concentration (Table 2). The lowest leaf N content (0.02%) and leaf K content (0.13%) were found in the BL variety grown in soil watered with 8000 ppm NaCl. At 8000 ppm NaCl, PS 881 had the highest leaf content of N (0.06%) and K (0.36%). There was some evidence that high Na content in solution hampered the absorption of N and K nutrients [24,25]. Therefore, it seems likely that the highest reduction of N and K nutrients absorption due to high Na⁺ occurred in the BL variety.

Table 2. Effect of salt concentration and variety on N and K content of sugarcane leaves.

| NaCl treatments (ppm) | N (%) | K (%) |
|-----------------------|-------|-------|
| PS 881                | PSJK 922 | BL   | PS 881 | PSJK 922 | BL |
| 0                     | 0.08 h | 0.08 h | 0.09 i | 0.63 c | 0.64 c | 1.00 d |
| 2000                  | 0.08 h | 0.06 ef | 0.06 ef | 0.61 c | 0.40 abc | 0.50 bc |
| 4000                  | 0.07 g | 0.06 ef | 0.05 d | 0.45 abc | 0.36 abc | 0.41 abc |
| 6000                  | 0.06 ef | 0.05 d | 0.04 e | 0.42 abc | 0.29 ab | 0.40 abc |
| 8000                  | 0.06 ef | 0.04 c | 0.02 a | 0.36 abc | 0.26 ab | 0.13 a |

Numbers followed by the same letters in each row and column for each variable are not significantly different

In a high concentration of the salt solution, Na⁺ is absorbed by sugarcane and accumulated in roots and leaves along with reduction and accumulation of K⁺ [26]. In this study, rising NaCl concentration increased Na content in the leaf of the three sugarcane varieties (Table 3). The highest content of leave Na occurred when 8,000 ppm NaCl solution was added, i.e., 0.64%; 0.63%, and 0.64% respectively in leaves of PS881, PSJK 992, and BL varieties.

Ratio K/Na is an indicator of tolerant plant variety to salt stress. The K/Na ratio was higher in
more salt-tolerant than in less salt-tolerant of sorghum [27]. In sugarcane, the highest content of Na\(^+\) is found in young leaves of the salt-tolerant cv. CP66-346 is associated with the lowest reduction in K\(^+\) concentration [25]. In the present study, the K/Na ratio of PS 881 and PSJK 992 sugarcane varieties was higher than that of BL variety, so the BL variety was the most susceptible to saline stress.

**Table 3.** Effect of salt concentration and variety on Na and ratio K/Na of sugarcane leaves.

| NaCl treatments (ppm) | Na (%) | Ratio K/Na |
|-----------------------|--------|------------|
|                       | PS 881 | PS JK 992 | BL | PS 881 | PS JK 992 | BL |
| 0                     | 0.44 a | 0.45 a | 0.44 a | 1.51 h | 1.46 gh | 2.27 i |
| 2000                  | 0.45 a | 0.46 a | 0.44 a | 1.38 g | 0.94 e | 1.15 f |
| 4000                  | 0.45 a | 0.50 a | 0.55 ab | 0.96 e | 0.82 d | 0.76 cd |
| 6000                  | 0.61 b | 0.63 b | 0.55 ab | 0.73 c | 0.47 b | 0.72 c |
| 8000                  | 0.64 b | 0.63 b | 0.64 b | 0.45 b | 0.41 b | 0.21 a |

Numbers followed by the same letters in each row and column for each variable are not significantly different.

3.3. Plant growth

At 4 months after planting, the interaction between NaCl concentration and sugarcane varieties significantly affected plant growth, expressed by the stalk diameter parameter. With rising NaCl concentration from 0 to 8000 ppm, the stalk diameter of tested sugarcane varieties was reduced (Table 4). The highest reduction of stalk diameter was observed in BL varieties. The stalk diameter of BL variety decreased from 31.8 mm (at 0 ppm NaCl) to 10.1 mm (at 8000 ppm NaCl) or 68.24\% of reduction. The biggest reduction of stalk diameter of BL varieties might be related to the lowest leave content of N, K, and ratio K/Na of the variety. A previous study found that the tolerance of sugarcane variety had better growth than susceptible variety under saline stress [8].

**Table 4.** Effect of salt concentration and variety on stalk diameter and number of tillers of sugarcane at 4 months after planting.

| NaCl treatments (ppm) | Stalk diameter (mm) | Number of tillers |
|-----------------------|---------------------|-------------------|
|                       | PS 881 | PS JK 992 | BL | PS 881 | PS JK 992 | BL |
| 0                     | 27.7 f | 19.2 cd | 31.8 g | 7.33 | 7.66 | 8.33 |
| 2000                  | 23.5 e | 18.3 c | 22.9 e | 7.00 | 7.00 | 7.66 |
| 4000                  | 19.4 cd | 17.7 c | 20.5 d | 6.33 | 6.33 | 6.66 |
| 6000                  | 14.2 b | 15.1 b | 18.6 cd | 6.00 | 6.33 | 6.00 |
| 8000                  | 13.7 b | 11.0 a | 10.1 a | 5.66 | 5.66 | 4.33 |

Numbers followed by the same letters in each row and column for each variable are not significantly different.

4. Conclusion

NaCl solution with more than 2000 ppm concentration negatively affected PS 881, PSJK 992, and BL varieties of sugarcane varieties. BL is the most susceptible among the three varieties under saline stress. The most susceptible of sugarcane variety due to saline was indicated by the lowest ratio K/Na in leave.

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