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Effect of natural silica to alleviate salinity stress of tomatoes (*Lycopersicum esculentum* Mill.) on entisol

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Abstract. The aims of this research are to know the effect of silica fertilizer (Si), salt stress and their interactions on the agronomic characteristics of tomato plants on Entisol soil. The experiment employed factorial randomized complete block design (RCBD) with 2 factors experiments i.e. level of conductivity, namely K0 = 0ds/m / pot, K1 = 1ds/m / pot, K2 = 2ds/m/pot, and K3 = 3ds/m/pot, and doses of Si fertilizer, namely S0 = 0g/pot, S1 = 5g/pot, S2 = 10g/pot, and S3 = 15 g/pot. There were 16 treatment combinations with 3 replications, in total 48 experimental unit were used. The variables observed were plant height, number of leaves, chlorophyll content, flowering age, number of flowers, number of fruits, fruit weight, and fruit volume. The application of Si fertilizer increased the number of tomato flowers. Salinity stress reduced plant height and weight of tomatoes. The interaction of silica fertilizer (Si) and salt stress influences the number of leaves and the number of flowers. The highest number of leaves was at the dose of KCl 1 ds/m/plant and silica fertilizer 5 g/plant, while the highest number of flowers was at the dose of KCl 3 ds/m/plant and silica fertilizer 10 g/plant.

1. Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the horticultural commodities which is one of the popular vegetables. However, the national tomato production is still below the consumption demand due to the fertile land. The alternative land that can be used for planting tomato is marginal land. such coastal entisol soil. Entisol soil is soil that has a constrain of physical, chemical and biological properties such a sandy texture, loose structure, fast permeability, low nutrients, low water holding power, low organic matter and salinity stress [1]. The main problem of coastal entisols, especially salinity stress can be eliminated by providing natural silica from sugarcane begase and zeolite. Sugarcane bagasse has a high silica content ie. of 55.5% to 70% [2]. Zeolite is a group of minerals produced from hydrothermal processes in alkaline igneous rocks or formed from volcanic activity which contains a high of silica [3]. However, there is lack of information on the effect of natural Si from zeolite to alleviate the effect of salinity stress. Therefore, it is necessary to conduct research on the effect of natural silica fertilization to alleviate the effect of salinity stress and the growth and yield of shallot plants on inceptisol

2. Methods

This research was conducted in ex-farm screen houses, Agronomy and Horticulture laboratories, and Soil Science laboratories, Faculty of Agriculture, Jenderal Soedirman University from January 2020 to



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April 2020. The materials used in the research included entisol soil, water, Si fertilizer consisting of zeolite and bagasse compost, KCl, urea fertilizer, SP-36 fertilizer, polybags and seeds of the Servo F1 tomato variety. The experimental design used was a factorial randomized block design (RBD) with 2 factors. The first factor is salt stress, namely $K_0 = 0 \text{ ds / m / plant}$, $K_1 = 1 \text{ ds / m / plant}$, $K_2 = 2 \text{ ds / m / plant}$, and $K_3 = 3 \text{ ds / m / plant}$. The second factor is Si fertilizer, namely $S_0 = 0 \text{ g / plant}$, $S_1 = 5 \text{ g / plant}$, $S_2 = 10 \text{ g / plant}$, and $S_3 = 15 \text{ g / plant}$, each factor is combined and obtained 16 treatment combinations. The treatment was repeated 3 times in order to obtain 48 experimental units. The variables observed were plant height (cm), number of leaves (strands), chlorophyll content (units), flowering age (day after plantation), number of flowers, number of fruits, fruit weight (gr), fruit volume (ml), and soil pH. The data obtained from the research results were analyzed using the F test at the 5% level, if it produces a real value, it is further tested using LSD (Least Significant Difference) with an error rate of 5%.

3. Results and discussion

3.1. The effect of Si fertilizer application on the agronomic characteristics of tomato plants

The results of the analysis in Figure 1 showed that the application of Si fertilizer has an impact on increasing the number of flowers along with the increasing dose of fertilizer. This effect is linear with $y = 0.26x + 29.8$ and $R^2 = 0.5729$. It is clearly indicated by the increase the number of flowers in the amount of 35 flowers at a dose of 15 g of silica fertilizer per plant. According to Hasiana et al. [4] application of Si fertilizer is able to increase the availability of P. This is because the soil components containing P ions are bound by Si ions so that P becomes available for plants. According to Agustinho et al. [5] the availability of P and Si in the soil provided a synergistic effect on soil Al, Mn, and As, but not on rice growth and P uptake.

Table 1. The agronomic characteristics of tomato plants on Si fertilizer application and salt stress

No	Variable	Treatment		
		Silica fertilizer (S)	Salt Stress (K)	Interaction S × K
1.	Plant height	ns	s	ns
2.	Number of leaves	ns	ns	S
3.	Chlorophyll	ns	ns	ns
4.	Flowering age	ns	ns	ns
5.	Number of flowers	s	ns	s
6.	Number of fruits	ns	ns	ns
7.	Fruits weight	ns	s	ns
8.	Fruits volume	ns	ns	ns
9.	Soil pH	ns	ns	ns

Information: s = significant and ns = not significant in the F test with a confidence level of 95% (α 5%)

The application of Si fertilizer did not significantly affect plant height, number of leaves, chlorophyll content, flowering age, number of fruits, fruit weight, fruit volume and soil pH (Table 1). Giving Si gave better results than the control treatment. Silica is not an essential element for plants but a functional nutrient that has an effect on plants [6]. Si application can increase the efficiency of photosynthesis, changes in the amount of biomass and nutrients [7]. According to Kalteh et al. [8] application of Si fertilizer can increase the amount of chlorophyll in plants. The higher the chlorophyll content, the greater the rate of photosynthesis produced. Additional elements such as Si are needed to make plants have a non-drooping leaf shape, so that the leaves are effective in capturing sunlight [9]. The use of silica decreases the transpiration rate of plants through thickening of the cuticle so that it can inhibit water loss in plants which results in an increase in the rate of photosynthesis [10]. Fertilization plays a role in increasing pH, especially in sandy soils. Based on the research results of Abdillah et al. [11], giving silica increased pH by 3.1% compared to controls. This increase is because the silica containing zeolite undergoes a silicate hydrolysis process which produces OH^- ions.

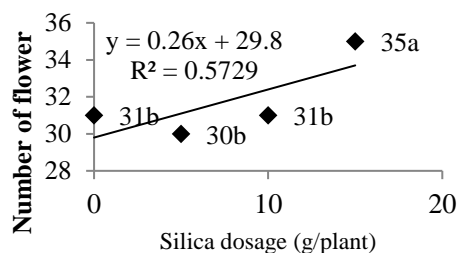


Figure 1. Effect of Si fertilizer dosage on the number of flowers.

3.2. The effect of salt stress on the agronomic characteristics of tomato plants.

3.2.1. Plant height. The results of the analysis in Figure 2 showed the effect of salt stress on reducing the height of tomato plants. The linear graph decreased with the increase in the KCl dose given the equation $y = -3.714x + 95.701$ and $R^2 = 0.8287$. Salinity can reduce the height of tomato plants because it causes water difficulties to be absorb due to the osmotic pressure. Water deficit can cause the loss of turgor plants [12]. Water is a raw material that is needed by plants to carry out metabolism. The need for water that hinders absorption and transportation can cause cell division to be disrupted and inhibited [13]. The increase in salt concentration will inhibit the absorption of water by plant roots, thereby affecting photosynthetic activities which will inhibit plant growth [14].

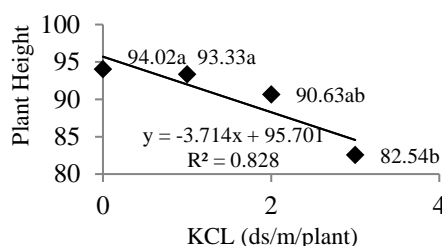


Figure 2. Effect of salt stress on plant height.

3.2.2. Fruit weight. The effect of salt stress decreases fruit weight with increasing KCl dose which is indicated by the equation $y = -1.01x + 25.74$ and $R^2 = 0.8594$ (Figure 3). Fruit weight per plant and fruit weight per fruit decreased under salt stress. The decrease in fruit weight is due to the reduced size of the fruit produced due to the shrinking roots under salt stress, thereby reducing water and nutrient uptake which results in decreased yields and affects fruit weight [15]. Salinity stress can affect nutrient absorption in plants due to excessive Na^+ and Cl^- ions and inhibits the absorption of K^+ , Ca^{2+} , NO_3^- ions. These nutrients are very important in the formation of fruit. This causes a decrease in fruit weight so that its size becomes small [16].

The application of salt stress did not significantly affect the number of leaves, chlorophyll content, flowering age, number of flowers, number of fruits, fruit volume and soil pH. The application of salt stress decreased the yield with increasing dose. The number of tomato leaves decreased significantly as the salinity concentration increased. This is a form of plant adaptation to reduce evaporation due to the water deficit obtained due to disruption of the water and nutrient transportation system [17]. High salinity content causes a decrease in chlorophyll content due to an increase in chlorophyllase activity and causes metabolic irregularities in producing nitrogen compounds such as proline [18], so that plants use mechanisms to avoid stress by accelerating their life cycle [12]. Increasing the KCl dose given increases soil pH. The pH of saline soils can vary over a wide range, but most are close to neutral or slightly alkaline. Saline soils with $\text{ESP} > 15$ are referred to as alkaline saline soils which have a high pH and tend to become slightly impermeable to water and aeration when dissolved salts are leached [19].

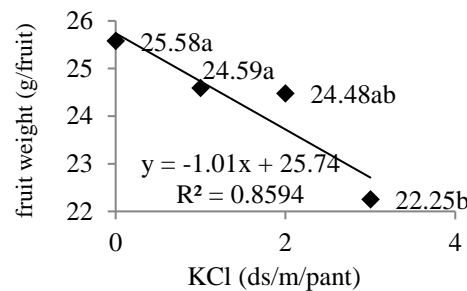


Figure 3. Effect of salt stress on fruit weight.

3.3. The interaction of silica fertilizer and salt stress on the agronomic characteristics of tomato plants. Salinity stress is a condition in which salt can dissolve in excessive amounts and is bad for plant growth [20]. This problem is due to the low water supply during growth, which causes a deficiency of mineral ions, organic acids and sugars [21]. The addition of Si fertilizer is used as an abiotic stress enhancer. The accumulation of the element Si in the form of silicic acid ($\text{Si}(\text{OH})_4$) in the cell walls of leaves, roots, and stems gives benefits to plants, which helps reduce ionic toxicity by increasing antioxidant enzymes during stress [22].

3.3.1. Number of leaves. The salt stress treatment decreased the number of leaves. This illustrates that this treatment makes the distribution of assimilates not focused on the formation of new leaves but is divided with other plant parts [23]. The addition of Si fertilizer has the potential to make plants have erect (not drooping) leaves so that the leaves are effective in capturing sunlight radiation for the optimal and efficient photosynthesis process [10]. This is supported by the opinion of [24], carbohydrates produced from photosynthesis are used by plants in the process of meristem cell division. New leaves develop from primordial leaves that are formed in the shoot apex meristem and occur when the meristem is active in cell division, so that the shoots will grow leaf buds.

Table 2. LSD test results for 5% of the interaction between Si fertilizer and salt stress on the number of leaves

Treatment	Number of leaves			
	Dosage of natural silica fertilizer. g / plant			
Salinity stress levels ds / m / plant	0	5	10	15
0	60 Aa	30 Cc	32 Cc	40 BCbc
1	36 Cc	55 ABab	39 BCbc	40 BCbc
2	40 BCbc	48 ABc	48 ABc	35 ABc
3	45 ABCabc	43 ABCabc	38 BCbc	47 ABCabc

Note: Numbers followed by different capital letters on the same row and different lowercase letters in the same column show significantly different results according to LSD at the 5% level.

3.3.2. Number of flowers. Increasing the number of flowers at increasing the dose of KCl as a response to plant adaptation to salinity stress. The condition is gripped by salt, the process of water absorption in plants is hampered, resulting in water shortages. Plants respond to water deficiency by reducing the rate of transpiration by covering the stomata and reducing the leaf surface area [25]. The response of stomatal closure is carried out by producing the hormone ABA (Abscisic Acid) from leaf mesophyll cells. The ABA hormone also plays a role in leaf shedding and accelerates plant aging, which is marked by the formation of premature flowers [26]. The application of Si fertilizer causes the plant to maintain the number of flowers. Si applied to plants has an effect on increasing the photosynthetic capacity. This has a positive correlation with growth rates such as the number of productive branches and the number of

flowers. Productive branches have flowers on each axillary base of the branch, so the more productive branches, the number of flowers produced. This correlation is the result of vegetative growth which is influenced by the availability of water, minerals and organic uptake from the soil [27].

Table 3. LSD test results 5% The interaction between Si fertilizer and salinity stress on the number of flowers.

Treatment	Number of flowers			
	Dosage of natural silica fertilizer. g / plant			
Salinity stress levels ds / m / plant	0	5	10	15
0	35 ^{ABCabc}	22 ^{Ee}	31 ^{ABCabcd}	36 ^{Aa}
1	27 ^{CDe}	31 ^{ABCDabcd}	33 ^{ABCDabcd}	27 ^{BCDbcde}
2	35 ^{ABab}	32 ^{ABCDabcd}	31 ^{ABCDabcd}	26 ^{Dde}
3	36 ^{Aa}	37 ^{Aa}	34 ^{Abc}	33 ^{Abcd}

Note: Numbers followed by different capital letters on the same row and different lowercase letters in the same column show significantly different results according to LSD at the 5% level.

4. Conclusions

Application of natural Si fertilizer increases number of tomato flowers. Level of salinity decreases the plant height and weight of tomato fruits. Natural Si fertilizer effectively alleviates the salinity stress of tomatoes, it mainly represented in the number of leaves and number of flowers.

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