The Study of Silica (Si) and Salinity on the Growth and Yield of Shallot Plant (*Allium ascalonicum* L.) in an Entisol Soil

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Abstract. One of the problems encountered by coastal sandy land is the high concentration of salt which can cause limited water uptake, and ion poisoning to the plants. Silica is potential nutrient to solve salinity problem in coastal sandy land. The objectives of this experiment are to examine the effect of salinity conditions on the growth and yield of shallots in an Entisol. The study was conducted from August to November 2020 in the screen house of the Faculty of Agriculture and the Laboratory of Agronomy and Horticulture, Faculty of Agriculture, Jenderal Soedirman University. The experimental design used was a factorial randomized block design (RBD) 4 × 3 with three replications. Fertilizer Si consisted of 4 levels i.e. control or 0 g Si/pot; 10 g Si/pot, 20 g Si/pot, and 30 g Si/pot. The salinity (K) comprised 3 levels of dose: control; 2 dS/m/pot, and 4 dS/m/pot. There were 12 treatment combinations with 3 replications (36 experimental units). Each experimental unit was planted with 2 plants. The observed variables were plant height, number of leaves, fresh root weight, dry root weight, number of tillers, root volume, number of bulb, bulb diameter, fresh bulb weight, dry bulb weight. The results showed that the application of natural silica increases the number of leaves, the number of tillers and the number of bulb with an optimal dose of 11 g per plant. The increased level of salt reduced the weight of fresh roots, the number of tillers, the weight of fresh bulb, the weight of dry bulb, the number of bulb, and the diameter of the bulb. The effect of combination of Si fertilizer and salinity condition was found on the number of leaves, dry root weight, root volume and number of tillers.

Keywords: Shallots · silica · salinity · coastal Entisols

1 Background

Shallots (*Allium ascalonicum* L.) is a spicy horticultural commodity group that is mostly consumed for the main cooking spice (Irawan *et al.*, 2017). Onion consumption in Indonesia is 4.56 kg/capita per year or 0.38 kg/capita per month (Rahayu *et al.*, 2016). Production of Shallot in Indonesia has not reached the domestic demand, thus the productivity of shallots needs to be increased to meet the target of national production (Directorate General of Horticulture, 2019).

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The two possible ways to increase national production of shallot are through intensification and extensification (Mulyani & Irsal, 2008). Coastal sandy land (Entisols) is considered a potential marginal land in Indonesia to overcome the shortage of land availability for agricultural cultivation. However, Entisol has physical, chemical and biological properties that are less favourable as ithas a sandy texture, weak structure, fast permeability, low water holding and storage capacity and low nutrients and organic matter and high salt levels in the soil (Supriyo et al., 2018). These conditions may cause a number of problems such as limited water uptake, and ion poisoning (Jones, 1981) and increase osmotic pressure which results in inhibition of nutrient and water absorption by plants (Muliawana et al, 2016).

One alternative way that can be used to overcome problems in Entisol soils is the provision of silica material (Karnilawati *et al*., 2015). Silica is one of the second most abundant chemical elements in the earth's crust (lithosphere) which is 27.6% and is absorbed by almost all plants in the form of mono silicate acid (mono silicic acid) or Si(OH)4. Silica serves to strengthen the walls of the epidermal tissue, vascular tissue, reduce water shortages, and inhibit fungal infections (Makarim et al., 2007). Sources of natural silica (Si) can be found in nature in the form of organic materials or inorganic materials such as sugarcane begasse and zeolites. Sugarcane bagasse is bagasse which is used as raw material to produce silica because it contains 55.5% to 70% natural silica (Kristianingrum, 2011). Zeolite is an alumina silicate mineral, which is composed of AlO4 and SiO4 units which can form a negative charge structure and have pores.

Based on the above problems, the objectives of this study were: (1) to examine the effect of natural silica on increasing the growth and yield of shallots on Entisol soils. (2) to examine the effect of soil salt level conditions on the growth and yield of shallots on Entisol soils, and (3) to determine the effect of combination of natural silica and level of salt conditions on the growth and yield of shallots on Entisol soils.

2 Research Methods

The research was conducted from August to November 2020 at Screen House, Faculty of Agriculture, Jenderal Soedirman University. The materials used in the study included Entisol soil, water, silica (Si) fertilizer consisting of zeolite and bagasse compost, polybags and onion bulbs of the bima Brebes variety.

The tools used include stationery, polybags, plastic clips, paper labels, digital scales, film bottles, rulers, calipers, nameplates, observation sheets, calculators, pH meters, Lux meters, and thermohygrometers.

Experimental design. This research was a pot experiment using a factorial 4 × 3 Randomized Block Design (RAK) with three replications. The factors are:

1. Si (S) with 4 levels

S0 = Control or without Si fertilizer

S1 = 10 grams Si/pot (20.44 g zeolite

+16.71 g bagasse charcoal)

S2 = 20 grams Si/pot (g zeolite 40.88 g zeolite+ 33.43 g bagasse charcoal)

S3 = 30 grams Si/pot (g zeolite 61.32 g zeolite+50.15 g bagasse charcoal)

2. Level of Salt (K) with 3 levels, namely: K0 = Control

Table 1. The combination of silica (Si) treatment and salt level.

Treatment	K0	K1	K2
S0	S0K0	S0K1	S0K2
S1	S1K0	S1K1	S1K2
S2	S2K0	S2K1	S2K2
S3	S3K0	S3K1	S3K2

K1 = 2 dS/m/plant (10 g pure KCl) K2 = 4 dS/m/plant (15 g pure KCl)

Combination of silica (Si) treatment and salt level can be seem on Table 1.

Based on Table 1, 12 treatments were obtained with 3 replications so that there were 36 experimental units. Each experimental unit contained 2 plants, so that the total of all plants in the experiment was 72 plants.

Observation Variables

The observed variables were plant height (cm), number of leaves (strands), fresh root weight (g/clump), dry root weight (g/clump), number of tillers, root volume (cm^3), number of bulbs/clump, bulb diameter (mm), fresh bulb weight (g/clump), dry bulb weight (g/clump).

Data analysis

The data obtained from the results of the study were analyzed using the F test, if it produced a real value, it was further tested using DMRT with an error rate of 5% and regression.

3 Result and Discussion

The analysis of variance (F Test) was undertaken to examine the effect of natural silica and salt levels condition on the growth and yield of shallot plants which included several observation variables including: plant height (cm), number of leaves (strands), fresh root weight (g/clump), dry root weight (g/clump), number of tillers, root volume (cm^3), number of bulbs/clump, bulb diameter (mm), fresh bulb weight (g/clump), dry bulb weight (g/clump).

4 Effects of Natural Silica on the Growth and Yield of Shallot

4.1 Number of Leaves

As indicated in Figure 1, the relationship between the application of natural silica fertilizer and the number of leaves followed a quadratic equation $y = -0.0158x^2 + 0.3593x + 19.121$ with $R^2 = 0.5522$. The optimum dose of Si fertilizer was achieved at 11.37 g which provided the highest number of leaves of 21.16 strands. This indicates that the applications of higher doses of silica fertilizer may reduce the number of leaves as the rate of transpiration is reduced. According to Liferdi (2007), excessive silica fertilizer

Table 2. Matrix of Effect of Natural Silica and Salt Levels Condition on Growth and Yield of Shallots

No	Variable	Perlakuan		
		S	K	S × K
1	**Plant Growth**			
A	Plant height (cm)	tn	tn	tn
B	Number of leaves (strands)	**N**	tn	**n**
C	Fresh root weight (g/clump). (g)	tn	tn	tn
D	Dry root weight (g/clump)	tn	**n**	**n**
E	Number of tillers	**N**	**n**	**n**
F	Root volume (cm^3)	tn	tn	**n**
2	**Plant Yield**			
A	Number of bulbs/clump	**N**	**n**	tn
B	Bulb diameter	tn	**n**	tn
C	Fresh bulb weight (g/clump)	tn	**n**	tn
D	Dry bulb weight (g/clump)	tn	**n**	tn

Note: tn = no significant effect n = significant effect, S = Natural Silica (Si), K = Salt levels, S × K = Natural Silica (Si) and Salt levels

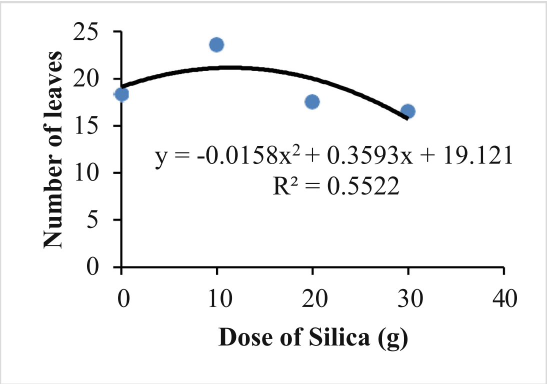

Fig. 1. Effects of silica dose on the number of leaves of shallots

applications might cause an antagonistic effects, as a result of the increase of pH which reduce the nutrient bioavailability in the soil, thereby reducing the number of plant leaves. Increasing concentrations of silica in the plants will certainly be able to build stronger cell walls, but the use of excessive concentrations will hamper plant growth (Dewantoro, 2017).

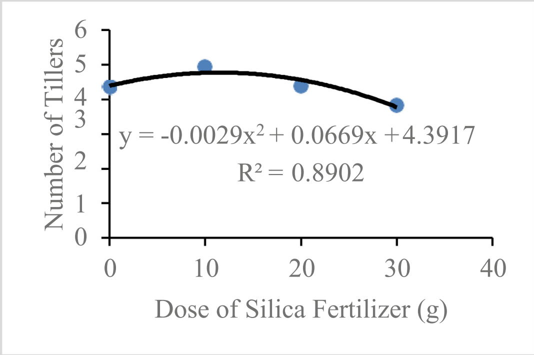

Fig. 2. Effects of silica Fertilizer on number of shallot tillers

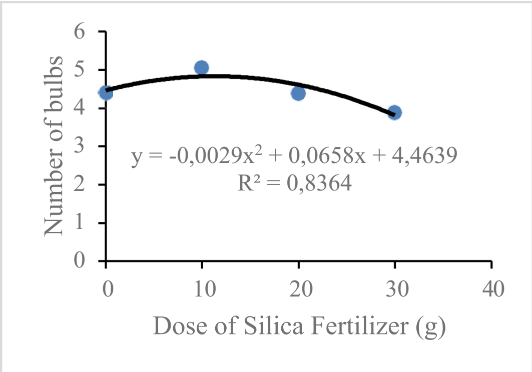

Fig. 3. The effects of Silica fertilizer on number of bulbs

4.2 Number of Tillers

As can be seen from Figure 5, the relationship between silica fertilizer application and the number of tillers was quadratic with the equation $y = -0.0029x2 + 0.0669x + 4.3917$ with $R^2 = 0.8902$. The optimum dose of silica was achieved at 11,5 g giving the highest number of tillers of 4.77/clump. Silica is needed in the process of plant cell division as energy in the formation of new tillers. This is in line with Zulputra *et al.* (2014), that the number of tillers increased with increasing P uptake due to silica applications as phosphorus is essential to the plants in the process of cell division and as energy in every plant metabolic process. According to Yohana (2013), the accumulation of assimilate during the photosynthesis process can increase the number of tillers in plants (Fig. 2).

4.3 Number of Bulbs

The results showed that relationship of silica fertilizer application and the number of bulbs was quadratic with the equation $y = -0.0029x2 + 0.0658x + 4.4639$ with $R^2 = 0.8364$. Based on the Figure 3, the optimum dose was achieved at 11,34 g which

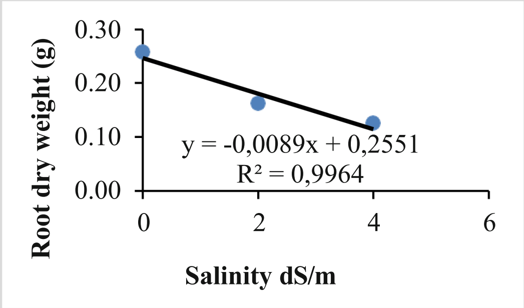

Fig. 4. Effects of salinity on root dry weight of shallots

generated the highest number of bulbs (4.83/clump). This could be attributed to a number of mechanisms. The absorption of natural silica fertilizer is known to increase the number of tillers which in turn promote the development of bulbs. The application of Si fertilizer can also increase the bioavailability of P. Soil components containing P ions are bound by silica ions so that P becomes available to plants (Hasiana et al., 2017). Elemental P is needed as an ingredient for the formation of certain proteins that help assimilation and accelerate the bulb formation phase (Lingga, 2007).

5 The Effects of Salinity on the Growth and Yield of Shallots

5.1 Root Dry Weight

Figure 4 shows that dry root weight of shallots was conversely related with the degree of salinity.

This relationship could be described by a negative linear regression $y = -0.0089 \times 0.2551$ with $R^2 = 0.9964$. This result is in accordance with the work of Sugiono and Samiyarsih (2005), that the higher the concentration of applied salt, the lower the dry weight of the plant. Quinet, (2010) found that plants would experience growth inhibition due to excessive salinity condition which could interfere with metabolic processes in plants. This conditions affect the ability of roots to absorb water and nutrients from the medium, as a result, reduced water supply causes photosynthesis to decrease.

5.2 Number of Tillers

Figure 5 shows that the treatment of salinity and the number of tillers negatively linearly correlated with the equation $y = -0.0607 \times 4.881$ with $R^2 = 0.6843$. The decrease in the number of tillers was caused by the roots shrinking under salinity condition, thereby reducing the uptake of water and nutrients resulting in a decrease in the number of tillers and yield (Alsadon *et al.*, 2013)

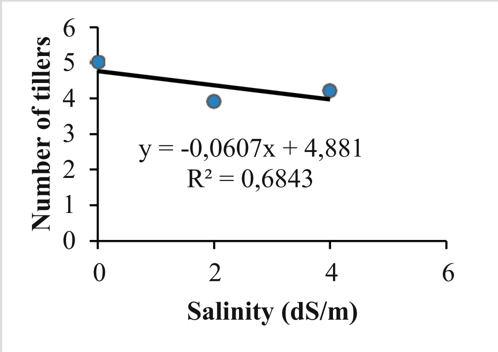

Fig. 5. Effect of salinity on the number of tillers of shallots.

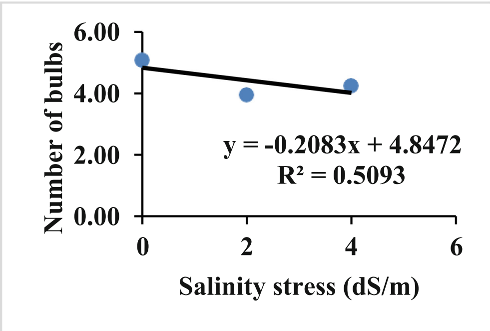

Fig. 6. Effects of salinity on number of bulbs of shallots

5.3 Number of Bulbs

Based on Figure 6. shows that the treatment of salinity on the number of tubers, linearly with the equation $y = -0.2083 + 4.8472$ with $R2 = 0.5093$. It is suspected that the plants were exposed to salinity condition. Salinity condition can affect nutrient uptake in plants due to excessive $Na+$ and $Cl-$ ions and inhibit the absorption of $K+$, $Ca2+$, $NO3-$ ions. These nutrients are very important in the formation of the number of tubers causing a decrease (Mardhiana et al., 2018).

5.4 Bulb Diameter

Based on Figure 7. shows that the application of salinity to bulb diameter linearly with the equation $y= -1.1286x + 18.805$ with $R2 = 0.9478$. According to Yunita (2016) salinity can cause a decrease in water potential in the media so that plants are difficult to absorb water and nutrients. nutrients from the growing medium. It is known that water and nutrients are needed in the process of bulb formation and enlargement.

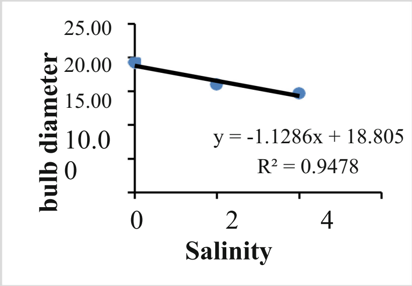

Fig. 7. Effect of salinity on bulb diameter of shallots.

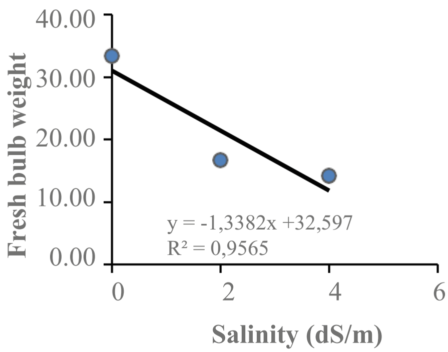

Fig. 8. Effect of salinity on the weight of fresh bulbs of shallots.

5.5 Fresh Bulb Weight

Based on Figure 8. shows that the application of salinity to the weight of fresh bulbs, the higher the salt concentration given, the smaller the weight of the fresh bulbs obtained linearly with the equation $y= -1.3382x + 32.597$ with $R2 = 0.9565$. High doses of salt can reduce the weight of fresh bulbs of shallot plants. According to Chen et al., (1998), the decrease in fresh bulb weight of stressed plants is the impact of the low water potential in the soil so that the plants are dehydrated, and transpiration reduction occurs. The further impact of these two processes is the low absorption of dissolved materials from the soil and/or the low biosynthesis of new materials in plants.

5.6 Bulb Dry Weight

The degree of salinity was inversely correlated with dry weight of fresh shallot bulb. The higher the salt concentration given, the smaller the weight of the fresh bulbs obtained. The relationship was described by negative linear regression with the equation $y = -1.3382 \times 32.597$ with $R^2 = 0.9565$ (Fig. 9).

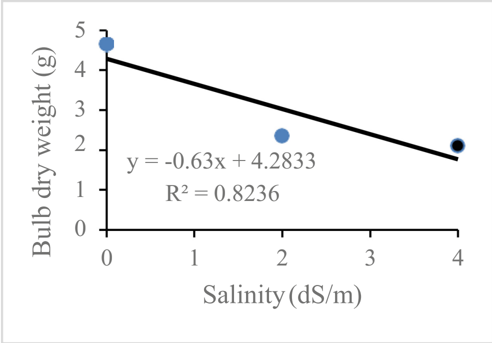

Fig. 9. Effects of salinity on bulb dry weight of shallots

According to Chen et al., (1998), the decrease in fresh bulb weight of stressed plants is the impact of the low water potential in the soil so that the plants are dehydrated, and transpiration reduction occurs. The further impact of these two processes is the low absorption of dissolved materials from the soil and/or the low biosynthesis of new materials in plants.

6 Interactive Effects of Silica Fertilizer and Salinity on the Growth and Yield of Shallots

6.1 Interactive Effects on Number of Leaves

Table 2 shows that the best treatment was obtained at a dose of Si 10 g per plant with a salinity of 2 dS/m. As salinity decreased the number of leaves, the distribution of assimilate would not be focused on the formation of new leaves but divided with other plant parts (Zhani et al., 2012). In salt- stressed conditions, the process of water absorption in plants is hampered, resulting in a lack of water for plants. Plants respond to water shortages by reducing the rate of transpiration by closing stomata and reducing leaf surface area (Fischer & Fukai, 2003). To reduce salt stress in plants can be done by giving silica nutrients. Silica is able to reduce the harmful effects of various abiotic and biotic stresses including salt stress (Ma, 2002). Tisadale *et al.* (1985) stated that Si silicate in the soil besides being a plant nutrient, also plays a rolein reducing Fe and Mn which are in toxic conditions. Si silicate also affects the fixation of phosphorus so that its availability increases, thereby increasing the number of leaves (Table 3).

6.2 Interactive Effects on Root Dry Weight

The results of the experiment showed that at a Si dose of 20 g per plant with a salinity of 2 dS/m per plant and 0 dS/m, a Si dose of 10 g per plant with a salinity of 4 dS/m per plant and 0dS/m, and a Si dose of 30 g. per plant and a salinity of 0 dS/m per plant gave no different treatment. Treatment of exposure to salinity affects root dry weight but with the provision of silica it is beneficial for various types of plants, under biotic and abiotic

Table 3. Results of DMRT ($P < 0.05$) on effects of Si fertilization and salinity levels on number of leaves of sallots

Treatment	Number of leaves			
	Si fertilizer dose (g/plant)			
Salinity level (dS/m/tanaman)	0	10	20	30
0	13,5ab	20,7c	20,6bc	18,8abc
2	23,5cd	28,4d	17,2abc	17,6abc
4	17,7abc	19,3abc	17,7abc	12,5a

Note: Numbers followed different letters at the same column are significantly different are significantly different $P < 0.005$)

Table 4. Results of DMRT test ($P < 0.05$) % on the effects of application Si and salinity on the root dry weight of shallots.

treatment	Root dry weight (g)			
	Dose of Si fertilizer (g/tanaman)			
Salinity dS/m/	0	10	20	30
0	0,15a	0,22b	0,20b	0,24b
2	0,13a	0,15a	0,25b	0,12a
4	0,13a	0,25b	0,16a	0,12a

Keterangan: Angka yang diikuti huruf yang berbeda pada kolom dan baris yang sama menunjukkan hasil yang berbeda nyata menurut DMRT pada taraf 5%.

stress conditions. Si in plants causes plantroots to be stronger so that nutrient absorption becomes more intensive. According to Romero Aranda *et al.* (2001) that salinity stress can be decreased with silica application. Silica is able to induce an increase in water storage capacity, thereby depleting Na in plant tissues. Si has the ability to reduce the negative effects associated with NaCI or KCL− induced salinity stress on root growth. Giving silica. with the appropriate dose, root growth will be positively correlated to the stress of a plant (Amrullah, 2015) (Table 4).

6.3 Interactive Effects on the Root Volume of Shallots

See Table 5

Table 5. Results of DMRT test (P < 0.05) on the effect of Si fertilizer and salinity on the root volume of shallots.

Treatment	Root volume			
	Dose of silika fertilizer (g/plant)			
Salinity dS/m/tanaman	0	10	20	30
0	1,3abc	1,9abcd	2,8d	1,5abcd
2	1,0ab	1,3abc	2,4cd	0,6a
4	1,2abc	2,0bcd	1,3abc	0,8ab

Note: Numbers followed by different letter in the same column are significant according to DMRTat P < 0.05

Tabel 6. Hasil Uji DMRT 5% Pengaruh antara pemupukan Si dan stres kegaraman terhadap jumlah anakan tanaman bawang merah.

Treatment	Number of tillers			
	Dose of Si Fertilizer (g/plant)			
Level of salinity (dS/m)	0	10	20	30
0	5,5d	3,5ab	4,0abc	5,1cd
2	4,8bcd	4,8bcd	5,1cd	3,1a
4	4,8bcd	4,1abcd	4,1abcd	3,1a

Note: Numbers followed by different letter in the same column are significant according to DMRTat P < 0.05

6.4 Interactive Effects on Number of Tillers

As can be seen from Table 6, the best treatment was obtained at a dose of Si 20 g per plant with a salinity of 0 dS/m (no salinity) or a salinity of 2 dS/m. Similar result was obtained with the dose of S1 10 g per plant with a salinity of 4 dS/m. The presence of silica in plants can improve the root system. The roots become stronger and longer so that they are more effective in absorbing nutrients (Putri *et al.*, 2017). The silica (Si) nutrients available at appropriate doses are thought to be able to help provide the plant's N, P, and K nutrient requirements.

7 Conclusions

1. The applications of natural silica fertilizer increased the number of leaves, the number of tillers and the number of bulbs with an optimal dose of 11 g per plant.
2. Increased salinity reduced fresh root weight, number of tillers, fresh bulb weight, dry bulb weight, bulb number, and bulb diameter.
3. The interaction effect of Si fertilizer and salinity was found on the number of leaves, dry root weight, root volume and number of tillers. The combination of Si fertilizer

at a rate of 10 g/plant and the salinity of 2 dS/m/plant gave the highest number of leaves of 28.41 strands. Combination of Si fertilizer at 20 g/plant and the salinity of 2 dS/m/plant gave the highest dry root weight of 0.25 g. The combination of Si fertilizer 20 g/plant and the salinity of 0 dS/m/plant gave the highest root volume weighing 2.8 cm^3. The combination of Si fertilizer 20 g/plant and the salinity of 2 dS/m gave the highest number of tillers of 5.1 tillers.

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