

Effects of Gypsum and Zeolite on Nutrient Uptake and Shallot (*Allium ascalonium* L.) Growth on Irrigated Saline Entisol

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ABSTRACT

Entisol is a weakly-developed soil with a diverse fertility, and has a potency for shallot cultivation. The central of shallot cultivation in Indonesia is in coastal areas which have a limiting factor of high soil salinity. High salinity will cause the nutrient uptake and plant growth disrupted. Zeolite and gypsum application can be a potential option to overcome the impact of high salinity. This study was arranged in a Completely Randomized Design (CRD) in a pot experiment with the treatments of combinations of shallot cultivars (Brebes = V1, Purbalingga = V2, Pemalang = V3) and soil amendments (gypsum 25 Mg ha⁻¹ = G, zeolite 15 Mg ha⁻¹ = Z, and Control = K). Each pot contained of 15 kg soil was irrigated by 1 L saline water of 2 dS m⁻¹ every day. The results showed that the irrigation and incubation with saline water increased pH, EC and SAR of soil, whereas zeolite and gypsum application decreased pH, EC, SAR. The application of gypsum significantly increased the nutrient uptake, therefore significantly increased the bulb diameter, and fresh and dry weight of shallot bulbs. The effects of amendements on the growth of shallot cultivars is different. Application of gypsum and zeolite showed better effect on cultivar Purbalingga, whereas the highest plant was measured in the treatment of zeolite on cultivar Pemalang.

Keywords: Gypsum, shallot, salinity, zeolit

ABSTRAK

Entisol merupakan tanah dengan perkembangan yang lemah dengan kesuburan tanah yang beragam, dan memiliki potensi untuk budidaya bawang merah. Pusat budidaya bawang merah di Indonesia terletak di daerah pantai dengan faktor pembatas salinitas tanah yang tinggi. Salinitas tanah yang tinggi dapat menyebabkan terganggunya serapan unsur hara dan pertumbuhan tanaman. Aplikasi zeolit dan gipsium dapat menjadi opsi yang potensial untuk mengatasi pengaruh salinitas yang tinggi. Penelitian ini disusun dalam Rancangan Acak Lengkap (RAL) dalam percobaan pot dengan perlakuan yang merupakan kombinasi antara kultivar bawang merah (Brebes = V1, Purbalingga = V2, Pemalang = V3) dan aplikasi bahan pembenah tanah (gypsum 25 Mg ha⁻¹ = G, zeolite 15 Mg ha⁻¹ = Z, dan kontrol = K). Setiap pot diisi dengan 15 kg tanah dan diirigasi dengan 1 L air salin dengan salinitas 2 dS m⁻¹ setiap hari. Hasil penelitian menunjukkan bahwa irigasi dan inkubasi dengan air salin meningkatkan pH, EC (*Electrical Conductivity*), dan SAR (*Sodium Adsorption Ratio*) tanah Entisol, sedangkan aplikasi zeolit dan gipsium menurunkan pH, EC dan SAR. Aplikasi gipsium meningkatkan secara signifikan serapan unsur hara, sehingga meningkatkan secara signifikan diameter umbi bawang merah dan berat basah dan berat kering umbi bawang merah. Pengaruh aplikasi pembenah tanah terhadap pertumbuhan tanaman bawang merah berbeda antar kultivar. Aplikasi gipsium dan zeolit menunjukkan pengaruh yang lebih baik pada kultivar Purbalingga, sedangkan tinggi tanaman tertinggi terukur pada perlakuan zeolit pada kultivar Pemalang.

Kata kunci: Bawang merah, gipsium, salinitas, zeolit

INTRODUCTION

Entisol is a weakly-developed soil, with potential fertility varies from highly productive for

shallot cultivation such as alluvial soils in floodplain, to low fertility on steep slopes or sandy areas (Buol 2005). According to Firmansyah and Sumarni (2013), Brebes is one of the central of shallot cultivation in Central Java, with alluvial soil types. Brebes has a shallot harvesting area of 26,645 ha in 2015-2016 (Central Bureau of Statistics of Central

Java Province 2017). The problem that is often experienced by shallot farmers in the northern coast region is the high level of soil salinity because of the intrusion of sea water that enters the irrigation canals. According to Hendrayana (2002) salinity occurs in the northern coast region due to the presence of sea water enters the plains and cannot be restrained, causing salt accumulation in the soil surface. Salinity is a condition of soil with high Na^+ concentration that can affect plant growth (Agus and Subiksa 2006). Yield of shallot planted in saline soils is about 18.39% lower than in acidic sulphate soils (Koswara 2007). High level of salinity causes plants to have low ability to absorb water from the soil, which can cause restricted plant growth and died (Provin and Pitt 2017). The soil salinity of 2 dS m^{-1} can reduce shallot yield by 12.82% (Cardon *et al.* 2003).

High salinity in soil is very detrimental, so the mitigation measures must be done. Saline soil management that has been carried out to mitigate the impact of soil salinity includes utilization of mycorrhiza to prevent Na^+ translocation from roots to shoots (Hadjah 2014), irrigation techniques using the pool-flow method (Kristanto and Purwarno 2017), and application of biochar and manure (Muharam and Saefudin 2016). The mechanism of improving soil salinity is by additional Ca and Mg that can replace Na ions in soil exchange complex and leach the Na into a deeper soil profile (Jarman 2013). The common ameliorant used for saline soil is gypsum (CaSO_4). Gypsum can be used for saline soil reclamation because gypsum can increase soil aggregation, soil percolation, and improve soil pH (Franzen *et al.* 2006). Haisheng *et al.* (2008) reported that gypsum can increase Ca^{2+} content and replace Na^+ to improve soil permeability. Size of aggregate in soil profile has correlation to the effectiveness of gypsum amendment in reducing exchangeable Na percentage (Lebron *et al.* 2006). Effectiveness of gypsum amendments depends on the soil water electrolyte and Ca concentrations resulted from gypsum dissolution, and on the efficiency of the Na–Ca soil exchange process (Amezketta *et al.* 2005). Application of gypsum decreased Na accumulation in soil applied with peat, however, increased rates of gypsum did not affect sodium content in the surface soil, but reduced the ratio of sodium to the other salts (Rahayu *et al.* 2011).

Zeolite is a hydrated alumina silicate crystal that contains three-dimensional alkaline or alkaline earth cations, acidic and has a molecular-sized pore (Atikah 2017). Zeolite can be utilized as a soil amendment that can increase soil porosity (Micu *et*

al. 2005), and play a role in reducing N leaching. According to Warmada and Titisari (2004), if there is a saturation of Na^+ from NaCl, the Na will be adsorbed by zeolite to re-form Na-Zeolite ($\text{Na}_2\text{Al}_2\text{Si}_3\text{O}_{10}\cdot 2\text{H}_2\text{O}$). Wang *et al.* (2012) reported that application of zeolite to saline soils with a solid ratio of 30% by weight of the soil can reduce sodium content from 563.0 ppm to 182.7 ppm. In addition, plant growth is also influenced by nutrient uptake, especially nitrogen, phosphorus and potassium that are essential nutrients (Sudarmi 2013). This study examined the effects of gypsum and zeolite amendments on N, P, K uptake and shallot growth on Entisol irrigated by saline water.

MATERIALS AND METHODS

Research Design and Treatments

This study was arranged in a Completely Randomized Design. A pot experiment was carried out from June to December 2017 in the Experimental Station of the Faculty of Agriculture, Sebelas Maret University. The treatments included (1) the soil amendments consisting of Gypsum (G), Zeolite (Z), and Control/without amendments (K); and (2) the shallot cultivars consisting of Brebes (V1), Purbalingga (V2) and Pemalang (V3). The soil used for the pot experiment was taken from the top soil of 0-30 cm of Entisol from Plesungan, Karanganyar, Central Java with the latitude of $7^{\circ}31' 54''\text{S}$; $110^{\circ}51' 40''\text{E}$. The properties of the soil is presented in Table 1. The pot used was 30 cm in diameter, filled with soil as much as 15 kg pot^{-1} and replicated 3 times. The soil was made saline by irrigating 2 dS m^{-1} of saline water at field capacity and incubated for 2 weeks, followed by the addition of zeolite 75 g pot^{-1} (CEC $223.15 \text{ cmol}(+) \text{ kg}^{-1}$) and gypsum 125 g pot^{-1} ($\text{CaSO}_4\cdot 2\text{H}_2\text{O}$ 93.87%) (Table 2). Fertilizers were applied at week 2 and week 4, based on the shallot fertilization recommendation by SNI (Indonesian National Standard), *i.e.* 250 kg ha^{-1} urea, 180 kg ha^{-1} ZA, 300 kg ha^{-1} SP-36, and 200 kg ha^{-1} KCl. Shallot bulbs were planted at the soil moisture level of field capacity. Irrigation was done by applying saline water with the salinity of 2 dS m^{-1} , obtained from a mixture of 1.28 gr of salt with 1 L of water. The saline water was applied as much as $1 \text{ L pot}^{-1} \text{ day}^{-1}$ to reach field capacity of the soil.

Soil and Plant Analysis

Soil samples were taken before planting and after harvest for soil characteristic and salt accumulation analyses. The parameters measured were plant height (every week until the maximum

Table 1. Soil characteristics before and after incubation.

Soil Chemical Properties	Before Incubation	After Incubation
pH	7.19 (N*)	7.29 (N*)
Organic-C (%)	1.14 (L)	1.18 (L)
Total-N (%)	0.20 (L)	0.17 (L)
Available-P (ppm)	2.84 (VL)	4.48 (VL)
Available-K (me 100 g ⁻¹)	0.67 (M)	1.21 (H)
Cation Exchange Capacity (cmol(+) kg ⁻¹)	18.04 (M)	18.31 (M)
Exchangeable Na (cmol(+) kg ⁻¹)	0.12 (L)	12.09 (VH)
Exchangeable Ca (cmol(+) kg ⁻¹)	12.03 (H)	1.12 (L)
Exchangeable Mg (cmol(+) kg ⁻¹)	0.93 (L)	0.35 (L)
Base saturation (%)	78.99 (H)	76.59 (H)
Electrical Conductivity (dS m ⁻¹)	0.14 (VL)	260.76 (M)
Sodium Adsorption Ratio (me 100 g ⁻¹)	0.05 (L)	12.11 (VH)
Texture	Loam	Loam

Note: *Criteria according to Balai Penelitian Tanah (2009): VL = Very Low; L = Low; M= Moderate; H = High; VH = Very High; N = Neutral.

plant growth), bulb diameter, wet weight of bulbs and dry weight of bulbs. The soil characteristics were analyzed according to the procedures proposed by Evianti and Sulaiman (2012), consisting of pH (soil: solution ratio 1:2.5), Electrical Conductivity (soil:solution ratio 1:5), and organic-C (Walkey and Black). Analysis of N uptake (Kjedhal), P and K uptake (wet ignition using HNO₃ and HClO₄) by the shallot plants were also determined.

Data Analysis

The data were analyzed using F-variance test at 5% significance level and continued by Duncan’s Multiple Range Test (DMRT). Correlation test was also performed to evaluate the relationship between the selected parameters.

RESULTS AND DISCUSSION

Effects of Gypsum and Zeolite on Soil Characteristics

Initial soil pH, Electrical Conductivity (EC) and Sodium Adsorption Ratio (SAR) increased after the salinity condition of the soil was reached and after the incubation (Table 1). The increase of pH was due to an increase of cation concentration that triggered the release of H⁺ into soil solution. According to Lubis *et al.* (2013) an increase in cation activity will result in an increase of soil pH. The increase of EC is thought to be due to the application of saline water irrigation (2 dS m⁻¹) during the incubation. The increase in soluble salt concentration will increase the EC (Eviati and Sullaiman 2012).

Table 2. Water content and CEC of gypsum and zeolite.

No	Parameter	Gypsum(CaSO ₄)	Zeolit
1.	water content (%)	1.91	6.79
2.	CEC (cmol(+) kg ⁻¹)	93.87	223.15

Table 3. The effects of application of gypsum and zeolite on the soil properties.

Soil Amandement	pH	EC (dS cm ⁻¹)	SAR (me 100g ⁻¹)
Gypsum (25 Mg ha ⁻¹)	6.68 c	0.17 b	0.24 b
Zeolit (15 Mg ha ⁻¹)	7.37 b	0.23 b	0.20 b
Without treatment	7.67 a	0.50 a	0.33 a

Note: The numbers followed by the same letters in the same column are not significantly different according to DMRT at 5% significance level.

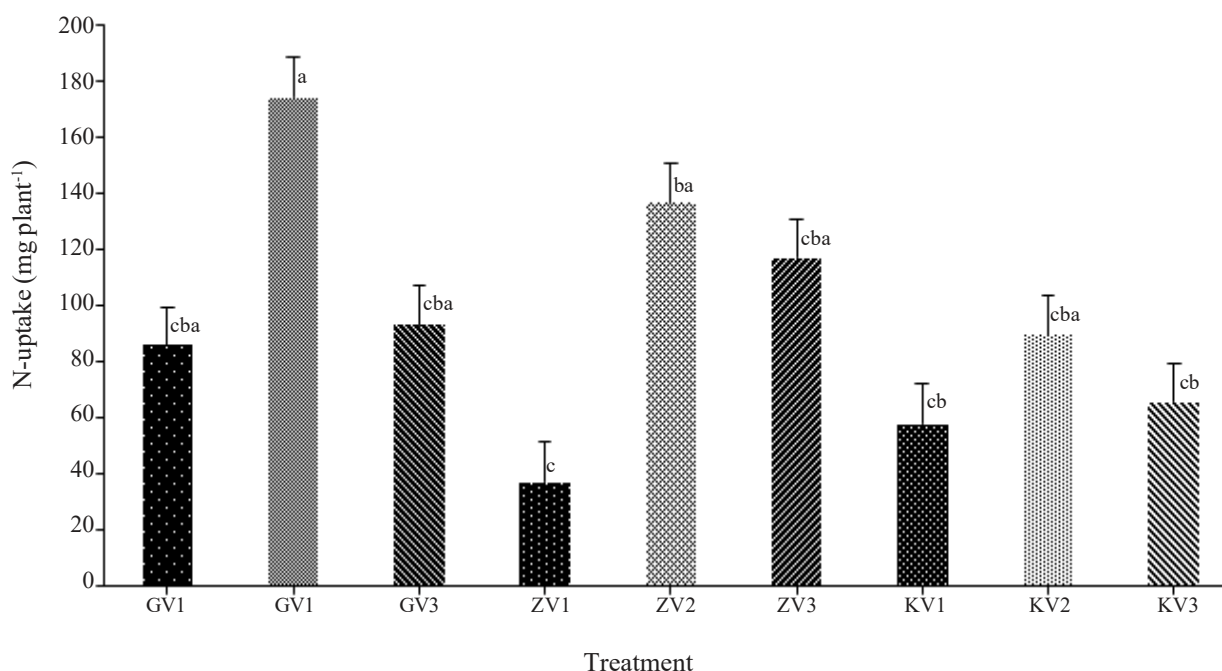


Figure 1. The uptake of N by shallot plants due to the application of gypsum and zeolite. The numbers above bars followed by the same letters are not significantly different according to DMRT at 5% significance level. G = Gypsum (25 Mg ha⁻¹), Z = Zeolit (15 Mg ha⁻¹), K = without treatment, V1 = cultivar Brebes, V2 = cultivar Purbalingga, V3 = cultivar Pemalang.

Table 1 showed that after the incubation, the SAR increased. The increase of Na⁺ concentration was due to the application of saline water irrigation. Rosmarkam and Yuwono (2014) showed that the increasing levels of Na lead to higher values of SAR. Application of gypsum showed a significant effect ($p < 0.05$) on soil pH and EC. Gypsum application at 25 Mg ha⁻¹ resulted in a lower pH of soil compared to the control treatment (Table 3). According to Suswati *et al.* (2012) sulfate (SO₄²⁻) contained in gypsum can reduce the soil pH. The application of gypsum affected simultaneously the decrease of pH, EC, and soil sodicity (Table 3). The decrease in soil pH due to gypsum application was probably due to the combination of more than one factor, mainly the replacement of sodium by calcium and the formation of neutral salts with SO₄²⁻ (Fattah 2014).

The application of gypsum resulted in lower soil EC compared to that in the zeolite and control treatments (Table 3). Purbajanti (2010) reported that the Ca contained in gypsum will decrease the SAR in saline soil, and SO₄²⁻ will decrease the pH into neutral condition. Addition of gypsum in saline soil with pH above 8 results in precipitation of sodium in the form of less soluble sodium sulfate (Na₂SO₄), resulting in the decrease of soil pH. Gypsum causes the soil rich in Ca²⁺ and the Ca²⁺ can replace Na⁺, which can be leached downward to the deeper soil layers. The Na⁺ ions rapidly decreased by FGD-

gypsum application and the soil pH was thus reduced (Sakai *et al.* 2012).

The application of zeolite also showed a significant influence ($p < 0.05$) on SAR (Table 3). Application of zeolite at 15 Mg ha⁻¹ can reduce the level of SAR by 24.5% from 0.33 me 100 g⁻¹ to 0.20 me 100 g⁻¹. The low SAR values in zeolite amendment are due to the Na⁺ ions are adsorbed by the zeolite. According to Warmada and Tirtasari (2004), Ca²⁺ on zeolite site is replaced by Na⁺ from the saline water that contains NaCl, and form Na-zeolite (Na₂Al₂Si₃O₁₀ 2H₂O). The Na⁺ ions from saline water that are adsorbed by zeolite result in the decrease of Na⁺ in the soil, thus the SAR also decreases. Wang *et al.* (2012) reported that the zeolite used at a solid ratio of 30% by weight of the soil can reduce the sodium content from 563.0 ppm to 182.7 ppm; and SAR from 70.3 me 100 g⁻¹ to 18.5 me 100 g⁻¹.

Effects of Gypsum and Zeolite on Nutrient Uptake

Nitrogen uptake by plants is influenced by soil properties, plant types and stages of plant growth (Fahmi *et al.* 2010). Gypsum amendment on shallot cultivar Purbalingga (GV2) resulted in the highest yield, which was similar to the effect of zeolite application (Figure 4). According to Suharyani *et al.* (2012) the application of gypsum can reduce Na⁺

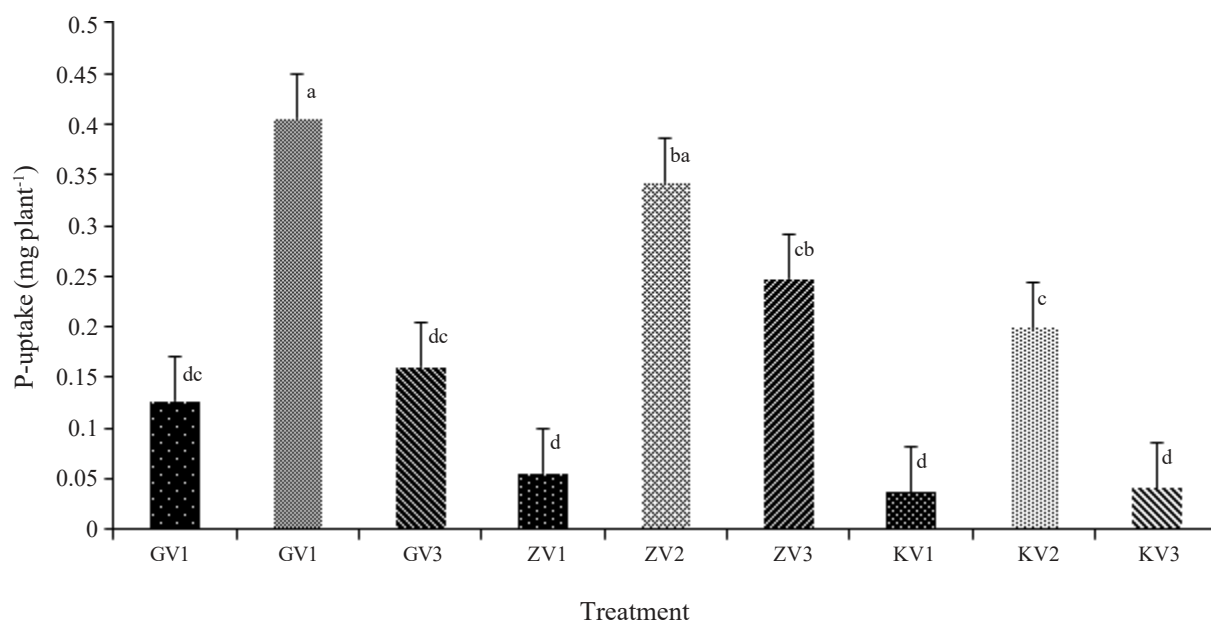


Figure 2. The uptake of P by shallot plants due to the application of gypsum and zeolite. The numbers above the bars followed by the same letters are not significantly different according to DMRT at 5% significance level. G = Gypsum (25 Mg ha⁻¹), Z = Zeolit (15 Mg ha⁻¹), K = without treatment, V1 = cultivar Brebes, V2 = cultivar Purbalingga, V3 = cultivar Pemalang.

in saline soils which has an effect on the availability of nutrients that can be taken up by the roots of plants. Uptake of nutrients such as nitrate and ammonium in some plants will be reduced due to the presence of NaCl that can increase the salt level in the soil, which further reduces the activity of nitrate (Parida and Das 2004). According to Sembiring *et al.* (2005), N₂ fixation by biological processes and soil mineralization will be reduced due to excessive absorption of Na.

Phosphorus is one of the macro nutrients, even though the need of P is not that much as nitrogen and potassium (Rusmarkam and Yuwono 2014). Phosphorus in shallots plays a role in increasing root development, so that it can facilitate and accelerate the absorption of soil nutrients. Phosphorus also plays a role in improving the quality and yield of plants, thus preventing the weight loss of shallot bulbs

(Soepadi 1983 cited by Hamdani 2008). Gypsum amendment at 25 Mg ha⁻¹ was estimated to give a good influence on P uptake. This is indicated by the high P uptake by the cultivar Purbalingga applied with gypsum (GV2) (Figure 2). The high P uptake in this treatment can be due to the Ca in gypsum can bind P to form Ca-P in the soil, so that P is not easily leached from the soil. According to Uusitalo *et al.* (2012) gypsum amendment is effective for erosion control and as a potential technique to reduce the loss of P from agricultural soils that have high potential for P loss. Based on Figure 2, it shows that the control treatment resulted in low P uptake by shallot plants. It is suspected that the application of saline water irrigation (2 dS m⁻¹) caused soil salinity so that the P uptake by plants was low. According to Bano and Fatima (2009), soil salinity significantly reduces plant nutrient uptake, especially

Table 4. Effects of amendments on plant height (cm) and bulb diameter (cm) of different shallot cultivars.

Amendment	Cultivar					
	Brebes		Purbalingga		Pemalang	
	Plant height (cm)	Bulb diameter (cm)	Plant height (cm)	Bulb diameter (cm)	Plant height (cm)	Bulb diameter (cm)
Gypsum (G)	16.7 a	1.67 a	17.0 b	2.00 ab	14.3b	1.58 ab
Zeolit (Z)	17.0 a	1.30 a	18.0 ab	2.15 a	23.7 a	1.80 a
without (K)	13.4 b	1.46 a	20.2 a	1.59 b	14.9 b	1.25 b

Note: The numbers followed by the same letters in the same column are not significantly different by DMRT at 5% significance level.

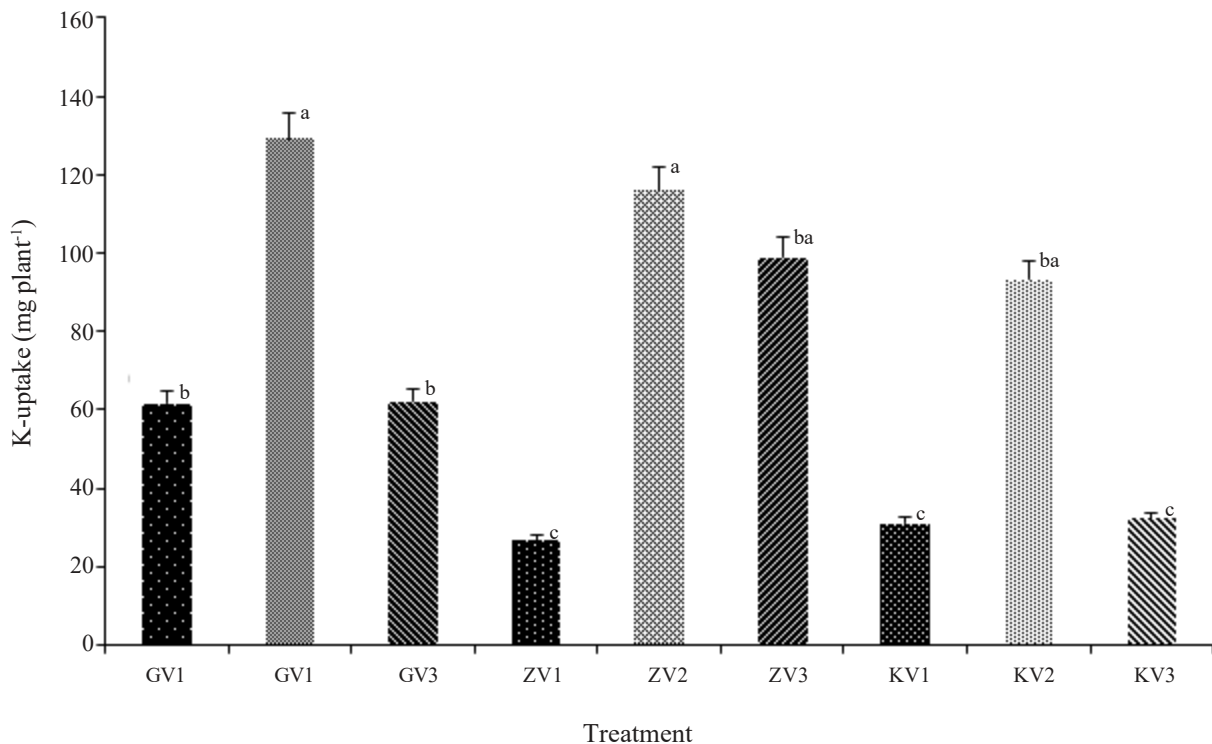


Figure 3. The uptake of K by shallot plants due to the application of gypsum and zeolite. The numbers above the bars followed by the same letters are not significantly different according to DMRT at 5% significance level. G = Gypsum (25 Mg ha⁻¹), Z = Zeolite (15 Mg ha⁻¹), K = without treatment, V1 = cultivar Brebes, V2 = cultivar Purbalingga, V3 = cultivar Pemalang.

phosphorus (P) because phosphate ions are precipitated by Ca ions in salt-affected soil.

Shallot plants take up more amounts of K than other plants (Jones *et al.* 1991), since potassium helps in the development of bulb cells and osmotic pressure in plants. One problem of plants grown on saline soils is the absorption of K⁺. The uptake competition between Na⁺ ions and K⁺ ions causes high absorption of Na⁺ will inhibit absorption of K⁺ (Amir *et al.* 2017). Applying saline irrigation (2 dS m⁻¹) continuously leads to the Na⁺ and Cl⁻ accumulation in the soil. Accumulation of salt inhibits the absorption of nutrients and water by plants. The highest K uptake was measured in the treatment of gypsum amendment on cultivar Purbalingga (GV2). This is presumably because the gypsum amendment was able to reduce Na⁺ and Cl⁻ deposits in saline soil. Wakeel (2013) reported that the K⁺ uptake by plants is affected by the presence of Na⁺, because K⁺ and Na⁺ are similar in physicochemical properties, therefore, Na⁺ competes with K⁺ in plant uptake. Low level of Na⁺ in soil applied with gypsum can be seen in Figure 1. According to Wahyuningsih *et al.* (2017), addition of 2.5 Mg ha⁻¹ gypsum to soil with a salinity of 3.2 dS m⁻¹ results in better potassium content in the canopy of green bean plants. In this study the addition of 25 Mg ha⁻¹ gypsum to soil with

a salinity of 2 dS m⁻¹ showed a positive influence on the uptake of potassium.

Effects of Gypsum and Zeolite on Plant Growth

Application of gypsum and zeolite had no significant effects on the growth of different shallot cultivars ($p > 0.05$). Cultivar Pemalang applied with zeolite amendment at 15 Mg ha⁻¹ resulted in the highest plant of 23.66 cm (Table 4). The measurement of plant height was carried out from the lower part of the plants just above the ground to the highest leaf tip. The application of zeolite in saline soil is able to control the available of Na at the low level, thus the plant can grow well. Purbalingga cultivar with zeolite treatment (ZV2) had the highest average bulb diameter (Table 4). The application of zeolite is considered to give a good effect on the shallot growth, because zeolite is able to bind Na⁺ from the soil applied with saline irrigation (2 dS m⁻¹). Maleki *et al.* (2012) reported that the use of zeolite at 15 Mg ha⁻¹ in saline soil increased the height of cassava plants by 7.08% and weight per plant by 14.51%. Addition of amendment also improved nutrient uptake by plant. According to Wahyudi (2009), improvement in soil conditions led to better growth and development of plant roots, thereby increasing nutrient uptake and improving plant

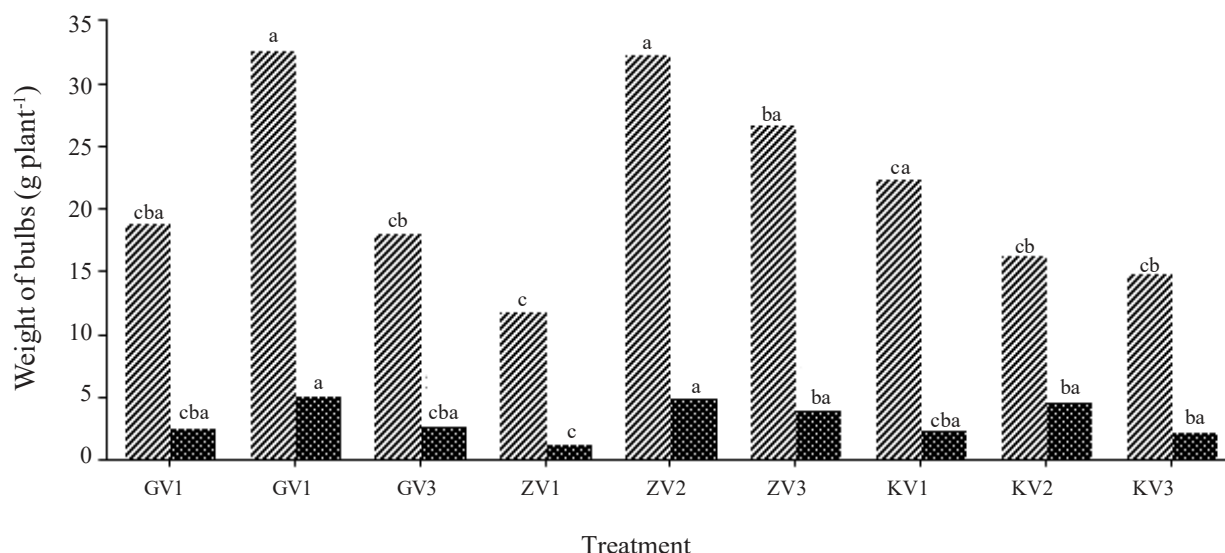


Figure 4. Fresh and dry weight of bulbs due to the application of gypsum and zeolite. The numbers above the bars followed by the same letters are not significantly different by DMRT at 5% significance level. G = Gypsum (25 Mg ha⁻¹), Z = Zeolite (15 Mg ha⁻¹), K = without treatment, V1 = cultivar Brebes, V2 = cultivar Purbalingga, V3 = cultivar Pemalang. ▨ : Fresh bulbs weight; ■ : Dry bulb weight.

growth. Setiyowati *et al.* (2010) reported that the larger bulb diameter indicates that the contents of organic compounds, such as carbohydrates, proteins, fats, *etc.* in the bulbs are high, so the compounds contained in the shallots with higher dry weight are also relatively high.

Gypsum amendment at 25 Mg ha⁻¹ on cultivar Purbalingga (GV2) resulted in the highest fresh weight and dry weight of bulbs compared to the other treatments (Figure 4). The high fresh weight of bulbs was due to the nutrient uptake in the treatment was high. The high fresh weight of shallots indicates a high level of water content in plants, this will cause the bulb size to be larger. The bulb weight showed a positive correlation with the bulb diameter ($r = 0.79$). According to Setiyowati *et al.* (2010), the increase of bulb fresh weight is due to the large amount of water taken up and the accumulation of photosynthesis in leaves are translocated for bulb formation. The application of gypsum amendment at 25 Mg ha⁻¹ to cultivar Purbalingga (GV2) showed better amount of nitrogen and phosphorus uptake by shallot plants than the other treatments. According to Firmansyah and Sumarni (2013) high nitrogen uptake by shallot plants causes higher plant dry weight and yield. Sumarni *et al.* (2012) reported that the increase of N, P and K uptake in plants can stimulate better plant growth (plant dry weight). This is because one that affects the dry weight of plants is the optimal photosynthesis. Photosynthesis can result in an increase in plant dry weight due to CO₂ uptake. This is because the dry weight of plants is a

net accumulation of CO₂ assimilation during the growth period (Dwijoseputro 1994). So that, if the N uptake is high, the dry weight of bulbs will also increase.

CONCLUSIONS

Saline incubation and saline irrigation on soil significantly increased soil pH, EC and SAR, while gypsum and zeolite application decreased pH, EC and SAR. Gypsum application at 25 Mg ha⁻¹ (G) significantly increased N, P and K uptake by shallot plants and was more effective on cultivar Purbalingga. The highest nutrient uptake was measured in the treatment of gypsum at 25 Mg ha⁻¹ on cultivar Puralingga (V2), therefore significantly increased the shallot bulb diameter, and fresh and dry weight of bulbs. The highest plant was measured in the treatment of zeolite at 15 Mg ha⁻¹ on cultivar Pemalang (V3).

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