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SHORT COMMUNICATION: **THE EFFECT OF SILICON ON THE ORGANICALLY GROWN LEAF LETTUCE GROWTH AND QUALITY**

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ABSTRACT. The purpose was to assess the effect of silicon on the leaf lettuce production. The experiments in the greenhouse were carried out in the spring 2014 at the Estonian Crop Research Institute. Treatments: 1) stabilized silicic acid treatment; 2) control. Si treatment (2 mL L^{-1} of silicic acid): First spray, when 1 true leaf was present; second spray was two weeks after spray 1; third spray was two weeks after spray 2. The pH of spray solution was 5.5. pH of spray solution was 5.5. Control plants were treated with water. The plants were 26% higher in Si variant. The width of leaf lettuce was 32% larger in Si variant. In leaf lettuce the phosphorus content was 14% higher, the content of calcium was 32% higher, the content of magnesium was 12% higher in Si variant than in control.

Introduction

Silicon is the second most abundant element in soil, comprising 50–70% of soil mass. All plants contain some Si in their cells and tissues (Olle, 2014). Still, the plant-available Si content in soils for plant growth and development may be insufficient. Plant available Si fertilization might help to provide plants with this nutrient. Silicon enhances growth, improves protection against pathogens (pests and diseases) and abiotic stresses like ions, salinity, water, temperature (Guntzer *et al.*, 2012; Thilagam *et al.*, 2014; Olle, Narits, 2015; Olle, Schnug, 2016). Silicon nutrition reverses succulence induced by high nitrogen and enhances crop growth and yield (Vasanthi *et al.*, 2014).

Silicon treated plants become stronger, sturdier and naturally more tolerant to drought, mineral imbalance and extremes of temperature (Bent, 2014). Silicon application could improve crop production under extreme climatic conditions (Shakoor, 2014; Shakoor, Bhat, 2014). Bioactive silicon helps to take up more nutrients and utilize water and minerals more efficiently, reducing their requirements for water, fertilizers and plant protection chemicals during cultivation (Bent, 2014).

Silicic acid agro technology (SAAT), developed by Dr Henk-Maarten Laane (Bent, 2014), is effective on almost every crop with increases of root system, loner stem/tillers, leaf area and chlorophyll content and nutrient uptake resulting in increased yield quantity and quality (Bent, 2014). Silicic acid agro-technology decreases biotic and abiotic stresses. Due to lower infection, rates pesticide use can be reduced (Bent, 2014). The product is safe for plants, soil, growers and consumers. The investigation was undertaken to determine effects of silicon on the leaf lettuce growth and quality. Those experiments were important to carry through because of silicon nutrition is substantive, because of it enhances growth, improves protection against pathogens (pests and diseases) and abiotic stresses like ions, salinity, water, temperature.

Materials and Methods

Experiments in a greenhouse were carried out in March to May of 2014 at the Estonian Crop Research Institute. In experiment leaf lettuce cv. 'Aficion' was used. The treatments were stabilized silicic acid treatment and a water control. Seed were sown in plastic trays in a heated glass greenhouse on 21 March 2014. When seedlings were 12 days-old they were transplanted into individual pot (9 cm diameter) containing Novarbo B2 Organic Biolan substrate (lime content 6 kg m^{-3}, fertilizer content 1.0 kg·m^{-3}, fertilizer N12:P6:K22, pH neutral) for organic cultivation.

Silicic acid (2 mL L^{-1}) was applied when 1 true leaf was present (14 April 2014) then again after 2 weeks

(28 April 2014), and with a third application in another 2 weeks (12 May 2014). The pH of treatment solution was 5.5. Control plants were treated with water with pH 5.5. The lighting at a plant level was approximately 380 lumen. Day and night temperatures were 20 and 18°C, respectively. Treatments consisted of 96 plants consisting of 12 plants in 8 replications. The experiment was arranged in a randomized complete block design (RCBD). On 15 May 2014 stem height and diameter of stem were recorded. Nitrate, nitrogen, phosphorus, potassium, calcium and magnesium contents were determined. The content of nitrogen was determined according to copper catalyst Kjeldahl Method (984.13). Nitrate contents were determined in extracts by Fiastar 5000. Phosphorus was determined with a Kjeldahl digest by Fiastar 5000 (AN 5242; Stannous chloride method, ISO/FDIS 15681). Potassium was determined with a flame photometric method (956.01). Determination of calcium was with the o-cresolphthalein complexone method (ISO 3696, in Kjeldahl Digest by Fiastar 5000). Magnesium was determined with the Fiastar 5000 (ASTN90/92; Titan Yellow method). Analyses of variance were carried out on the data obtained using the programme Agrobase. Fisher's LSD test was run on data.

Results

Treatment affected plant height with those treated with Si being taller than the controls variant (Table 1). The height increased by 26% in Si treated plants. Lettuce shoot width was affected by treatment as follows: in Si treated plants the width of lettuce plants increased by 32% (Table 1). Treatment did not affect leaf nitrate and nitrogen content (Table 2). The phosphorus content of lettuce leaves dry matter was higher in Si treated plants compared to control (Table 2). Si treatment increased the content of phosphorus in lettuce leaves dry matter by 14%. Potassium content in lettuce leaves dry matter was not affected by treatment (Table 2). The calcium and magnesium contents in lettuce leaves dry matter were higher in Si treated plants (Table 2). Si treatment increased the content of calcium in lettuce leaves dry matter by 22%. Si treatment increased the content of magnesium in lettuce leaves dry matter by 15%.

Table 1. Leaf lettuce transplant height (A) and width (B) as a result of treatment with silicon (Si) as opposed to the water control.

Item	Plant height (cm)		Plant width (cm)	
	Si	Control	Si	Control
Average	9.75	7.19	9.94	6.75
St. dev.	0.79	0.40	1.53	0.45
P	<0.001		<0.001	

Table 2. The content of nitrates in raw leaf lettuce transplant; the contents of nitrogen, phosphorus, potassium, calcium and magnesium in leaf lettuce as a result of treatment with silicon (Si) as opposed to the water control.

Item	Nitrate content (mg kg^{-1})		Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)		Calcium content (%)		Magnesium content (%)	
	Si	Control	Si	Control	Si	Control	Si	Control	Si	Control	Si	Control
Average	3.38	3.37	2.15	1.96	0.51	0.44	4.86	4.51	1.48	1.15	0.41	0.35
St. dev.	1.19	0.95	0.53	0.31	0.04	0.04	0.82	0.63	0.15	0.05	0.03	0.02
P	0.98		0.55		0.04		0.52		0.006		0.03	

Discussion

The leaf lettuce growth was enhanced due to treatment with Si as has been reported for other crops (Haghighi *et al.*, 2012; Torabi *et al.*, 2012; Olle, Narits, 2015; Zhu, Gong, 2014; Roohizadeh *et al.*, 2015). Silicon nutrition reverses succulence induced by high nitrogen and enhances crop growth and yield (Vasanthi *et al.*, 2014). Greger *et al.* (2011) found that biomass in lettuce was increased by Si and the root:shoot ratio was unchanged.

In this investigation, weight was not measured, but it can be assumed that increased height and width of plants the biomass is also increased. Application of Si can increase yield (Jarosz, 2014). Improved Si management is important to sustain crop productivity (Meena *et al.*, 2014).

By Si treatment, the elements phosphorus, calcium and magnesium contents were increased in leaf lettuce. Bent (2014) found that treatment with silicon increases nutrient uptake and that silicic acid agro-technology increases nutrient uptake by plants. Greger *et al.* (2011) reported that for some nutrients silicon in lettuce affected the uptake and distribution, while not affecting other nutrients. In the present investigation phosphorus was increased by treating leaf lettuce with silicic acid solution compared to the untreated control. In contrast, Greger *et al.* (2011) found that phosphorous decreased with Si in lettuce. Decrease of phosphorus is mainly a dilution effect; the amount of P was unchanged or increased because of the Si-induced increase of biomass (Greger *et al.*, 2011). Higher calcium content is useful in suppressing insect and disease attack and increasing transportability and storage quality (Olle, 2013). Increased magnesium after Si treatment is desirable because higher Mg reduces incidence of insect pests and diseases (Cakmak, 2013). Jayawardana *et al.* (2014) found that disease incidence was delayed by 2 days in plants treated with Si. Marodin *et al.* (2014) reported that Si reduced occurrence of fruit deformities. Foliar application of Si is effective against aphids (Guntzer *et al.*, 2012).

At a glance: silicon fertilisers with high plant-available silicon content have many potential benefits and sufficient Si supply aids healthy growth and product development. Applied silicon fertilisers interact positively with applied major and trace elements improving their agronomic performance and efficiency. Silicon fertilisers also enhance the plants' ability to resist or tolerate biotic stress such as attack of insect pests and fungal attacks (Bent, 2014; Smith, 2011; Zhu and Gong, 2014; Vasanthi *et al.*, 2014). Silicon fertilisers can help alleviate abiotic stresses due to acidity, salinity and toxicities. Silicon fertilisers can help reduce water loss and transpiration (Smith, 2011).

In addition to decreased susceptibility to fungal pathogens (and insects), the beneficial effects of adequate Si include reduced manganese and iron toxicity, reduced salinity and water stress, protection of leaves from ultraviolet radiation damage and increased growth in some plants (Smith, 2011).

Si treated plants become stronger, sturdier and tolerant to dryness and drought, mineral imbalance and extremes of temperature (Bent, 2014). Therefore, silicon application could improve crop production under extreme climatic conditions (Shakoor, 2014; Shakoor, Bhat 2014). Bent (2014) describes, that bioactive silicon helps to take up more nutrients and utilize water and minerals more efficiently, reducing their requirements for water, fertilizers and plant protection chemicals during cultivation.

Conclusion

Silicon promoted the growth (the height and the width) of lettuce plants and improved its nutritional quality, by increasing phosphorus, calcium and magnesium contents in leaves of lettuce.

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author contributions

MO contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript.

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