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THE EFFECT OF SILICON ON THE ORGANICALLY GROWN ICEBERG LETTUCE GROWTH AND QUALITY

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ABSTRACT. Si helps plants to mitigate with abiotic and biotic stresses because of Si-treated plants become stronger, sturdier and naturally more tolerant. The purpose of the investigations was to look the effect of Silicon on the iceberg lettuce growth and quality. There were two treatments: 1. stabilized silicic acid treatment; 2. control. The first spray, when 1 real leaf was present; the second spray was 2 weeks after spray 1; the third spray was 2 weeks after spray 2. First spray: 1 ml silicic acid was solved in 0.5 litre distilled water; second spray: 2 ml silicic acid was solved in 1 litre distilled water; third spray: 2 ml silicic acid was solved in 1 litre distilled water. pH of spray solution was 5,5. Control plants were untreated. Iceberg lettuce plants were taller and more bread in Si treatment compared to control. The content of NO_3, N, P, Ca was higher in Si-treated plants.

Introduction

Silicon is present in soils in large amounts, for example, Silicon dioxide is composing 50–70% of the soil mass. All plants tissues contain some Si (Olle, 2014). At the same time if Si is largely present in soils the amount of plant-available Si in soils for plant growth and development may be insufficient. Therefore plant-available Si fertilization might help to feed plants with this nutrient also. Many investigations have clearly demonstrated that supplying crops with adequate plant-available Si can suppress diseases and insects attacks on plants, improve environmental stress tolerance, and increase crop yield (Olle, 2014; Olle, Narits, 2015; Olle, Schnug, 2016).

At a glance: Silicon fertilisers with high plant available Silicon content have many potential benefits and sufficient Si supply aids healthy growth and productive development. Applied silicon fertilisers interact positively with applied major and trace elements improving their agronomic performance and efficiency. Silicon fertilisers also enhance the plant's ability to resist or tolerate biotic stress such as the attack of insect pests and fungal attacks (Bent, 2014; Smith, 2011; Zhu, 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).

Plant available silicon increases the translocation (movement) of nutrients within the plant and increases water efficiency by reducing transpiration. The benefit of a high plant available silicon content fertiliser product is that it delivers organic amorphous Si (as opposed to crystalline Si) in an easily accessible form to the crop root zone. Improved resistance to disease and pathogenic fungal attack due to Si applications has been reported for a number of crops (Smith, 2011). As most parasitic fungi penetrate the host by boring through the epidermal cell wall, Si in these walls may act as a mechanical barrier.

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). Silicon application could, therefore, 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.

The application of stabilized silicic acid is called the silicic acid agro-technology (SAAT). This technology was developed by Dr Henk-Maarten Laane (Bent, 2014). SAAT has been shown to be very effective on almost every crop with increases of the root system, longer stem/tillers, leaf area and chlorophyll content and nutrient uptake resulting in 15–50% more yield and higher quality (Bent, 2014). SAAT also decreases biotic and abiotic stresses. Due to a (much) lower infection rate, pesticide use can be reduced by (at least) 50%. The product is safe (for the plant, the soil, the farmer and the consumer) and ecologically friendly.

The purpose of the investigations was to look the effect of Silicon on the iceberg lettuce growth and quality.

Materials and methods

The experiments in the greenhouse were carried out in spring 2014 at the Estonian Crop Research Institute. In experiment iceberg lettuce Regina de Ghiacci variety was grown. There were two treatments: 1. stabilized silicic acid treatment; 2. control.

Each treatment consisted of 24 plants, within that one plot consisted of 6 plants in four replications. The experiment was repeated at the same time, *i.e.* in the first and second experiment seeds were sown on 21 of March 2014 and results were gathered on 15 of May 2014. The design of experiments was randomised block design.

Iceberg lettuce seeds were sown in plastic trays and seedlings were grown in a heated glass greenhouse. Seedlings were transplanted once into the individual pot (9 cm diameter), (4 of April 2014). Plants were grown in Novarbo B2 Organic Biolan substrate (lime content 6 kg m^{-3}, fertilizer content 1.0 kg m^{-3}, fertilizer N-P-K 12-6-22, pH neutral) for organic cultivation.

Silicic acid treatment was carried through as followed: First spray, when plants were growing and when 1 real leaf was present (14.04.14); the second spray was 2 weeks after spray 1 (28.04.14); the third spray was 2 weeks after spray 2 (12.05.14). Sprays were followed: First spray: 1 ml silicic acid was solved in 0.5 litre clean (distilled water, pH 5.8) water; second spray: 2 ml silicic acid was solved in 1 litres clean (distilled water, pH 5.8) water; third spray: 2 ml silicic acid was solved in 1 litre (distilled water, pH 5.8) water. pH of spray solution was 5.5. Control plants were untreated.

The greenhouse lighting at a plant level was approximately 150 µmol $m^{-2}s^{-1}$ from high-pressure sodium lamps. The plants were additionally lighted in the period of 18 hours (23.00–16.00). All plants were grown with a minimum day and night temperature of +20 °C and +18 °C, respectively.

On 15.05.2014 the height and stem diameter were recorded. The plants were measured before harvest. The contents of Nitrates, Nitrogen, Phosphorus, Potassium, Calcium and Magnesium were determined. Dry matter was determined according to standardised method by drying the biomass at 105 °C for overnight. The content of nitrogen was determined according to Copper Catalyst Kjeldahl Method (984.13). Nitrate contents were determined extracts by Fiastar 5000. The determination of Phosphorus was carried through in Kjeldahl Digest by Fiastar 5000 (AN 5242; Stannous Chloride method, ISO/FDIS 15681). The determination of Potassium was carried through by Flame Photometric Method (956.01). Determination of calcium was carried through by the o-Cresolphthalein Complexone method (ISO 3696, in Kjeldahl Digest by Fiastar 5000). The determination of Magnesium was carried through by Fiastar 5000 (ASTN90/92; Titan Yellow method). Analyses of variance were carried out on the data obtained using programme MS Excel 2010. Level of the significance was expressed conventionally: *** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$; NS not significant, $P > 0.05$. The error bars on the figures are presented as standard deviations (SD).

Results

The iceberg lettuce in Si variant was 31% higher than plants in control variant (Figure 1, a).

The breadth of iceberg lettuce was 17% larger in Si variant compared to control variant (Figure 1, b).

The content of nitrates in iceberg lettuce was 97% higher in Si variant compared to control (Figure 2, a).

The content of Nitrogen was 40% higher in Si variant compared to control (Figure 2, b).

In iceberg lettuce transplants the Phosphorus content was 25% higher in Si variant than in control (Figure 3, a).

The content of Potassium in iceberg lettuce was not statistically different (Figure 3, b).

The content of Calcium was 30% higher in Si variant compared to control (Figure 4, a).

The content of Magnesium in iceberg lettuce was not statistically different (Figure 4, b).

Discussion

In the present study, the iceberg lettuce crop growth was enhanced. In a similar way, several authors have reviewed the benefits of silicon application on crop growth (Olle, 2014; Zhu, Gong, 2014). In accordance, Heckman (2013) and Smith (2011) concluded that Si one of most important effects is a direct stimulation of plant growth and yield through more upright growth and plant rigidity.

In addition, silicon nutrition reverses the succulence induced by high nitrogen and enhances crop growth and yield (Vasanthi *et al.*, 2014). Greger *et al.* (2011) found accordingly that biomass in lettuce increased by Si with the unchanged proportion of root:shoot ratio.

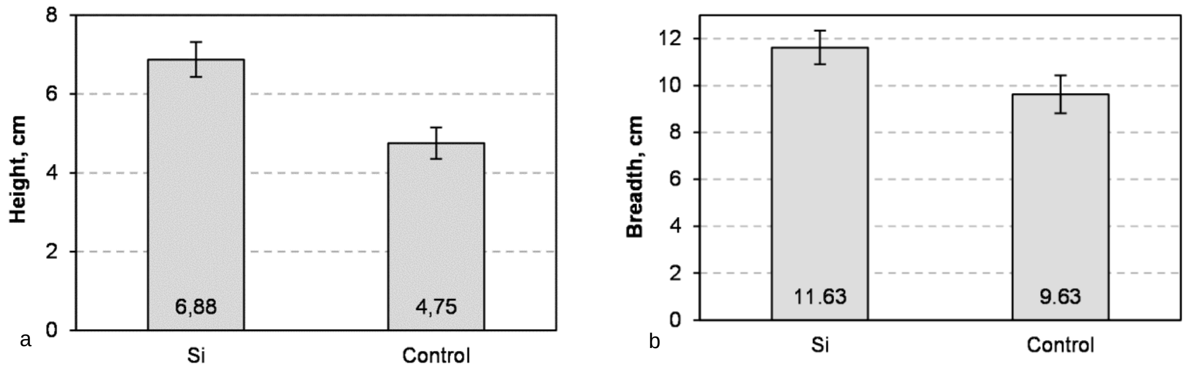

Figure 1. Iceberg lettuce transplant mean (± SD) height (a, ***) and breadth (b, ***).

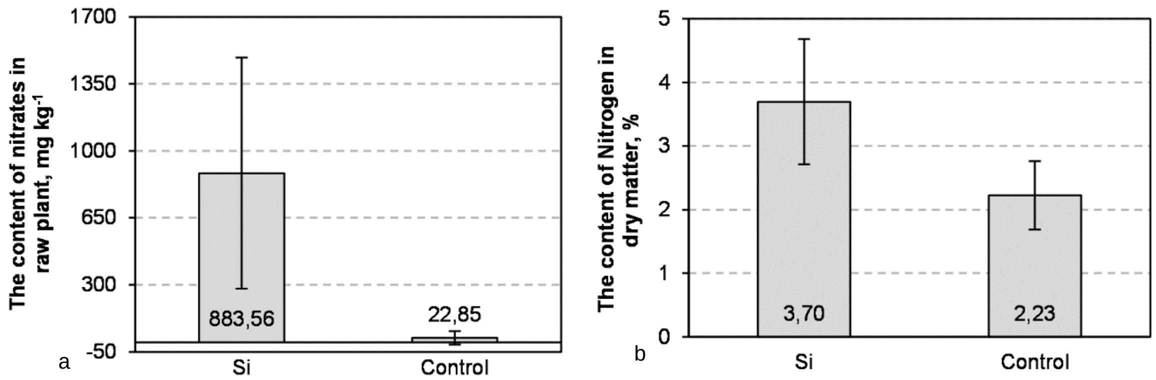

Figure 2. The mean (± SD) content of nitrates (a, *) in raw iceberg lettuce transplant and the content of nitrogen (b, *) in iceberg lettuce dry matter

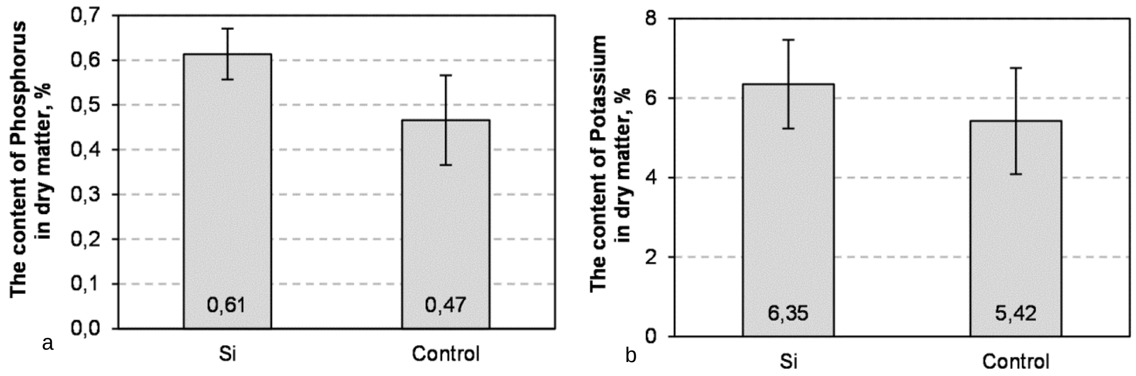

Figure 3. The mean (± SD) content of Phosphorus (a, *) and Potassium (b, NS) in iceberg lettuce dry matter

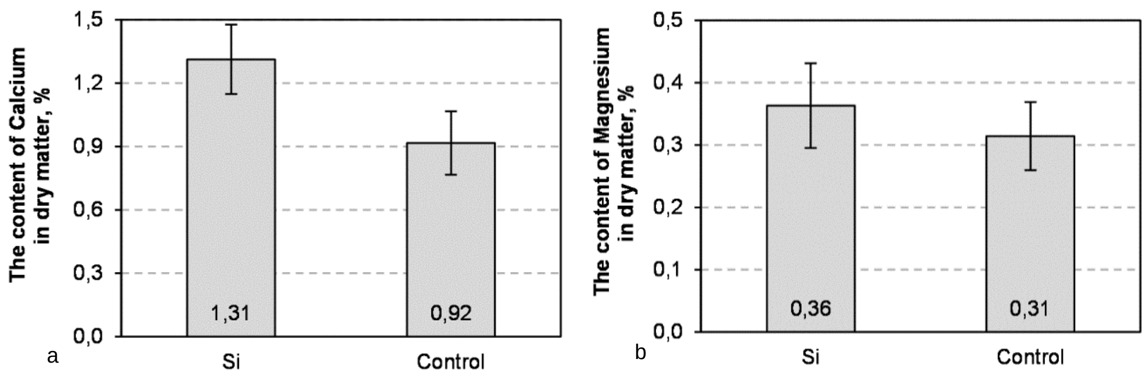

Figure 4. The mean (± SD) content of Calcium (a, *) and Magnesium (b, NS) in iceberg lettuce dry matter

In the present study, the content of NO_3, N, P, Ca were higher in Si-treated plants. Similarly, Smith (2011) found that applied silicon fertilisers interact positively with applied major and trace elements improving their agronomic performance and efficiency. Bent (2014) in the same way stated that silicic acid agro-technology (SAAT) is increasing nutrient uptake by plants. Greger *et al.* (2011) presented that for some nutrients Silicon in lettuce crop affected the uptake and distribution while others nutrients uptake and distribution were unaffected. While this situation was also in present investigation: Si treatment increased some nutrients uptake and did not affect others nutrients uptake.

Increased nutrients uptake could also influence plants negatively, because of: A high nitrate accumulation, which was present in our investigation, in plants might be undesirable, because it results in nitrite production, which is converted to nitric oxide by nitrate reductase and converted into the extremely toxic compound peroxynitrite under aerobic conditions, which is harmful to plant growth (Reddy, Menary, 1990). More seriously, the accumulation of peroxynitrite in humans may result in conditions such as chronic heart failure, diabetes, chronic inflammatory diseases, cancer, and neurodegenerative disorders (Pacher *et al.*, 2007).

In the present investigation, it was shown that Phosphorus contents were increased by treating plants with silicic acid solution compared to the untreated control. In contrast, Greger *et al.* (2011) found that Phosphorous decreased with Si in lettuce. The decrease of Phosphorus is mainly a dilution effect; in fact, the amount of P was unchanged or increased because of the Si-induced increase of biomass (Greger *et al.*, 2011). Phosphorus is needed especially for good root growth (Durner, 2013).

Present investigation also showed the increased Calcium contents in iceberg lettuce plants. A higher Ca content is beneficial, suppressing insect and disease attack and increasing transportability and storage quality (Olle, 2013; Olle 2015).

Conclusion

Iceberg lettuce was taller and more breadth in silicic acid treatment compared to control. The content of NO_3, N, P, Ca was higher in Si-treated plants. Silicon could be used in iceberg lettuce production. One solution how to decrease the content of nitrates should be found in future. Maybe different growth substrate with lower or totally absent N content could be used.

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Conflict of interest

The author declares that there is no conflict of interest regarding the publication of this paper.

Author contributions

MO designed and carried out trial and analyzed all data, made writing, editing and approved the final manuscript.

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