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Nutritional Value and Sensory Quality of New Potatoes in Response to Silicon Application

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Abstract: Since silicon regulates plant physiological and biochemical processes, it was hypothesized that foliar silicon application could contribute to improving the quality of new potatoes. This paper analyzes the effect of silicon (sodium silicate) on the nutritional value and sensory quality of new potatoes. Silicon was applied at the dose of 23.25 g Si·ha^{-1} or 46.50 g Si·ha^{-1} once at the leaf development stage (BBCH 14–16) or at the tuber initiation stage (BBCH 40–41) and twice, at the leaf development and tuber initiation stages. Potatoes were harvested 75 days after planting (the end of June). Silicon had no effect on the dry matter, total sugars and monosaccharides, protein, L-ascorbic acid or nitrate content in new potato tubers, but it increased the starch content under water deficit conditions. The most starch was accumulated by tubers following the application of 46.50 g Si·ha^{-1} at the leaf development stage (BBCH 14–16). Silicon did not affect the color of tuber flesh after cooking.

Keywords: sodium silicate; early crop potato; tuber quality; after-cooking darkening

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1. Introduction

Potatoes are a significant source of nutrients and bioactive compounds in the human diet, including carbohydrates (the predominant is starch), protein, vitamins (the predominant is vitamin C), minerals, dietary fiber, phenolics and other bioactive compounds. They also contain naturally occurring anti-nutrients, such as glycoalkaloids and nitrates, which, in high concentrations, are harmful to human health [1–3]. Nutrient and anti-nutrient content depend on the cultivar, growth conditions and harvest time [4–8]. Immature potato tubers (new potatoes) have higher amounts of many nutrients than at maturity. Tuber nutrient content decreases as the tuber matures [2]. The cooking method also affects the nutritional value of potatoes [9]. Apart from nutritional value, important quality characteristics of edible potatoes are their sensory properties, such as the taste, texture or the after-cooking darkening. The discoloration of cooked potatoes is caused by the oxidation of the colorless ferrous-chlorogenic acid compound formed during cooking to colored ferric-dichlorogenic acid. The degree of the darkening is cultivar-dependent but can be influenced by environmental factors and tuber maturity at harvest [10,11].

In recent years, potato growth has been greatly influenced by weather conditions. Drought is the most serious condition regarding potato productivity [12]. There is a relationship between the nutrient content in potato tubers and the physiological indicators of plant growth, such as the assimilation leaf area and chlorophyll content in leaves, fluorescence yield, efficiency of photosystem II (PS II) and plant growth rate [13]. Photosynthesis and photoassimilate distribution in plants under stress conditions are influenced by the intensity and duration of unfavorable conditions [14]. Drought influences sugar metabolism in plants. In tuber crops, drought stress affects starch synthesis. Drought stress caused a reduction in the glucose and fructose content and an increase in sucrose content in potato [8,15]. There is a relation between the glucose and sucrose content in potato tubers and the ADP-glucose pyrophosphoryalaze (ADP) activity involved in starch synthesis. Both of the sugars' activities affect the post-transcriptional oxydo-reduction properties of ADP-ase. An increase in the ADP-ase activity increases the starch synthesis in potato tubers [14].

In sustainable potato production, plant growth stimulants play an important role in mitigating environmental stresses. Previous studies have mostly focused on the use of organic biostimulants (microbial and non-microbial) in potato production [16]. There is scarce knowledge of the effects of mineral biostimulant use in potato production. Many researchers report the beneficial influence of silicon (Si) on the growth of crop plants through mitigating environmental stresses. Silicon alleviates plant environmental stresses by regulating the physiological and biochemical prosesses. It can contribute to mantaining the plant water balance, improving photosynthesis and nutrient uptake, regulating the activities of antioxidant enzymes and stress-tolerant gene expression and reducing oxidative stress [17–20]. Silicon increased the protein content in wheat [21]; the protein, vitamin C and total soluble solid content in cucumber [22,23]; the vitamin C, total phenol and total soluble solid content in tomato [24,25]; and the dry matter, total sugars, vitamin C and total soluble solids in strawberry [26], but had no effect on the sucrose and alpha-amino-nitrogen content in sugar beet [27]. Although potato is a Si-non-accumulator [28], soil or foliar application of silicon improved potato growth [29–31] and tuber yields [32–35]. Neither soil or foliar silicon (sodium silicate, stabilized silicic acid) application had an effect on the dry matter accumulation of tubers of very early cultivars under greenhouse conditions [28,29]. Foliar silicon (stabilized silicic acid) application increased or decreased the dry matter content in tubers of very early cultivars but did not affect the dry matter accumulation by tubers of late cultivars grown under open fields in Brazil [32]. Field experiments in Poland showed that orthosilicic acid increased the dry matter, starch and vitamin C content in tubers of the medium–early cultivar. It did not affect the dry matter accumulation by tubers of medium–late cultivars, but significantly reduced the nitrate content. Orthosilicic acid had no effect on the darkening of raw tubers [34,36]. In recent years, silicon nanoparticles has been used to mitigate environmental stresses in plants and for crop improvement [37,38]. Nano-chelate silicon fertilizers had no effect on the dry matter, starch, crude protein and ascorbic acid content in tubers of very early cultivars [39], but sodium silicate nanoparticles increased the dry matter content in tubers of late cultivars under salinity stress [33]. A study in Latvia showed that seed potato treatment by the plant growth activator lignosilicon (LSi), based on a wood lignocellulosic complex, resulted in an increase in dry matter and starch content and a decrease in the nitrate content in tubers of the medium–early cultivar [40].

Orthosilicic acid and silicate salts are the forms of silicon most commonly used to mitigate environmental stresses in plants [18]. The effect of foliar silicon (sodium metasilicate) application on the nutritional value and sensory quality of new potatoes was determined. In the study, it was hypothesized that the stimulation of plant growth by silicon application could improve the quality of new potatoes and that the changes in nutritient content and sensory quality depend on the silicon dosage and time of application.

2. Materials and Methods

2.1. Plant Material and Growth Conditions

The very early cultivar Catania (Europlant Pflanzenzucht GmbH, Germany), with medium–large soil and water requirements (recommended for organic cultivation), was grown [41]. Agrotechnics and plant protection are described in a previous paper by Wadas [35].

The field experiment was carried out at the Siedlce University of Natural Sciences and Humanities experimental field in 2016–2018. The experiment was located on Haplic Luvisol (LV-ha) with an acidic–slightly acidic reaction (pH_{KCL} 5.2–5.7), high content of available phosphorus (97–114 mg P·kg^{-1} of soil), medium–high content of potassium (93–124 mg K·kg^{-1} of soil) and low–medium content of magnesium (23–42 mg Mg·kg^{-1} of soil). Hydrothermal conditions during the potato growth period (Table 1) were determined on the basis on the index of plant water provision (Sielianinov's hydrothermal index) according to Skowera [42]. The soil and hydrothermal conditions are described in more detail in a previous paper by Wadas [35].

Table 1. Weather conditions during potato growing period.

Year	Temperature; °C			Rainfall; mm			Hydrothermal Conditions		
	April	May	June	April	May	June	April	May	June
2016	9.1	15.1	18.4	28.7	54.8	36.9	rather dry	rather dry	very dry
2017	6.9	13.9	17.8	59.6	49.5	57.9	very humid	rather dry	rather dry
2018	13.1	17.0	18.3	34.5	27.3	31.5	dry	very dry	very dry

2.2. Experimental Design

The effect of silicon in the commercial product Optysil (Intermag Ltd., Olkusz, Poland) on the nutritional value and sensory quality of new potatoes was investigated. The non-organic biostimulant Optysil contains 93 g Si (7.8 m/m) in the form of sodium metasilicate (Na_2SiO_3) and 24 g Fe (2 m/m) in the form of iron chelate (Fe-EDTA) in liters.

The field experiment was established as a split-plot design with a control object, with three replications. The experimental factors were as follows: silicon dosage (main plots)—23.25 g Si·ha^{-1} and 46.50 g Si·ha^{-1} (0.25 L·ha^{-1} and 0.50 L·ha^{-1} of Optysil); times of silicon application (subplot)—once at the leaf development stage (BBCH 14–16 stage) or tuber initiation stage (BBCH 40–41), and twice at the leaf development and tuber initiation stages (BBCH 14–16 and BBCH 40–41). Potato plants sprayed with water were used as a control (without silicon). A single control plot was located between the main plots. The plot area was 16.2 m^2 (96 plants per plot).

Potato harvest was performed 75 days after planting (the end of June). For laboratory studies, 50 different-sized tubers from each plot were taken. Fresh potato tubers were analyzed for dry matter with the gravimetric method [43], starch with the polarimetric method according to Ewers [44], total sugars and monosaccharides with the Luff–Schoorl method [45], crude protein with the Kjeldahl method [46], L-ascorbic acid with the titration method with 2,6-dichlorophenolindophenol (DCPIP) according to Tillmans [47], nitrates with the spectrophotometric method based on the Griess reaction [48] and the ascorbate–nitrate index (L_{AN}) calculated as the L-ascorbic acid/nitrate ratio [49].

The discoloration of cooked potatoes was also determined. The discoloration of tuber flesh was visually scored for ten tubers after 10 min and 2 h following boiling, using the 9-point Danish scale (9—no darkening, 1—the strongest darkening) [50].

2.3. Data Analysis

The analysis of variance (ANOVA) for the two-factor split-plot design with a control object was used to analyze the results of the three-year study. The orthogonal contrast was used to compare the test objects (treated with silicon) with the control (without silicon). Tukey's test ($p \leq 0.05$) was used to determine the least significant difference (LSD).

3. Results

3.1. Tuber Yield

The effects of silicon on tuber yields are described in a previous paper by Wadas [35]. Silicon application increased the early potato yield by an average of 4.94 t·ha^{-1} (23%) in 2016 and by 2.43 t·ha^{-1} (13%) in 2018, and improved the commercial value of the yield by increasing the share of medium-sized tubers. Under periodic water deficits (2016), the most practical was silicon application at 46.50 g Si·ha^{-1} in the tuber initiation stage, whereas, under drought conditions (2018), two silicon applications were used at 23.25 g Si·ha^{-1}.

3.2. Nutrient Content

Silicon (Si) did not affect the content of dry matter but increased the starch content, on average over the three-year period, by 3.8 g·kg^{-1} of fresh weight (FW) (Table 2). Silicon did not affect the total sugar and monosaccharide content.

Table 2. Effects of silicon (Si) on dry matter and carbohydrate content; mean ± standard deviation.

Treatment	Dry Matter % FW	Starch g·kg^{-1} FW	Total Sugars g·kg^{-1} FW	Monosaccharides g·kg^{-1} FW
Control	18.65 ± 2.92 a	117.3 ± 10.32 a	6.42 ± 0.45 a	2.00 ± 0.24 a
With Si	18.82 ± 2.70 a	121.1 ± 17.69 b	6.52 ± 0.44 a	2.11 ± 0.26 a

Means indicated with the same letters do not differ significantly at $p \leq 0.05$.

The starch accumulation by tubers under silicon application depended on the hydrothermal conditions. Silicon significantly increased the starch content only in 2018, in the warm and very dry period (Figure 1). In that year, Si-treated tubers had higher starch content, on average, by 14.5 g·kg^{-1} FW compared with the untreated control tubers.

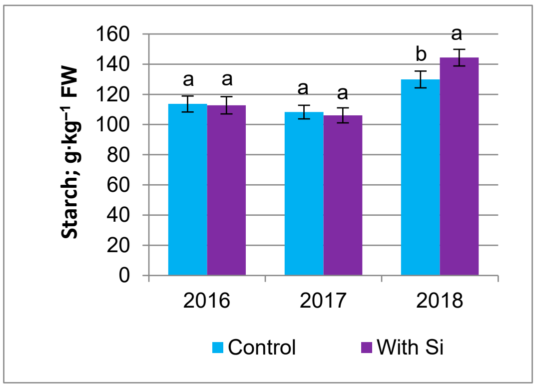

Figure 1. Effect of weather conditions and treatment on starch content; mean ± standard deviation. Means for each year indicated with the same letters do not differ significantly at $p \leq 0.05$.

The dosage and time of silicon application slightly affected the dry matter and carbohydrate content (Table 3). The significant effect of the interaction of the weather conditions, dosage and time of silicon application on the starch content was found (Figure 2). In 2018, the starch content was the highest following the application of 46.50 g Si·ha^{-1} at the leaf development stage.

Table 3. Effects of dosage and time of silicon (Si) application on dry matter and carbohydrate content; mean ± standard deviation.

Dosage and Time of Silicon Application	Dry Matter % FW	Starch g·kg^{-1} FW	Total Sugars g·kg^{-1} FW	Monosaccharides g·kg^{-1} FW
Silicon dosage; g Si·ha^{-1}				
23.25 g	18.93 ± 2.82 a	120.9 ± 17.29 a	6.56 ± 0.42 a	2.13 ± 0.24 a
46.50 g	18.71 ± 2.63 a	121.3 ± 18.41 a	6.50 ± 0.48 a	2.10 ± 0.27 a
Time of silicon application				
BBCH 14–16	18.89 ± 2.84 a	120.7 ± 18.01 a	6.50 ± 0.52 a	2.07 ± 0.25 a
BBCH 40–41	18.83 ± 2.14 a	121.8 ± 15.39 a	6.68 ± 0.34 a	2.13 ± 0.24 a
BBCH 14–16 and BBCH 40–41	18.73 ± 2.72 a	120.8 ± 18.18 a	6.42 ± 0.44 a	2.15 ± 0.27 a

BBCH 14–16, leaf development stage; BBCH 40–41, tuber initiation stage; BBCH 14–16 and BBCH 40–41, leaf development and tuber initiation stages. Means indicated with the same letters do not differ significantly at $p \leq 0.05$.

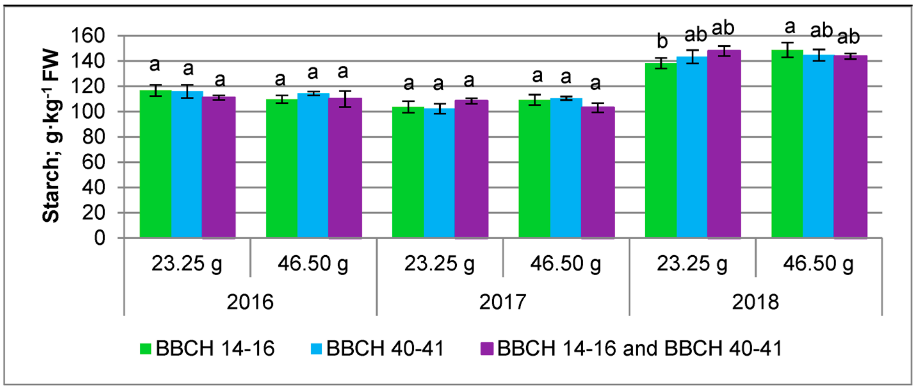

Figure 2. Effect of weather conditions, dosage and time of silicon application on starch content; mean ± standard deviation. BBCH 14–16, leaf development stage; BBCH 40–41, tuber initiation stage; BBCH 14–16 + BBCH 40–41, leaf development and tuber initiation stages. Means for each year indicated with the same letters do not differ significantly at $p \leq 0.05$.

Silicon did not affect the content of protein, L-ascorbic acid or nitrates in new potato tubers (Table 4). Following silicon application, there was only a slight decrease in nitrate content and, as a result, a slight increase in the ascorbate–nitrate index (I_{AN}).

Table 4. Effects of silicon (Si) on protein, L-ascorbic acid and nitrate content; mean ± standard deviation.

Treatment	Protein g·kg^{-1} FW	L-Ascorbic Acid mg·kg^{-1} FW	Nitrates mg·kg^{-1} FW	Ascorbate–Nitrate Index (I_{AN})
Control	15.25 ± 1.51 a	116.6 ± 6.20 a	92.22 ± 6.38 a	1.27 ± 0.12 a
With Si	15.64 ± 1.69 a	116.4 ± 8.05 a	89.24 ± 7.10 a	1.31 ± 0.10 a

Means indicated with the same letters do not differ significantly at $p \leq 0.05$.

The dosage and time of silicon application did not affect the protein and nitrate content in tubers. The time of silicon application had a significant effect on the L-ascorbic acid content. Regardless of silicon dosage, the L-ascorbic acid content was the highest with two silicon applications (Table 5).

Table 5. Effects of dosage and time of silicon (Si) application on protein, L-ascorbic acid and nitrate content; mean ± standard deviation.

Dosage and Time of Silicon Application	Protein g·kg^{-1} FW	L-Ascorbic Acid mg·kg^{-1} FW	Nitrates mg·kg^{-1} FW	Ascorbate–Nitrate Index (I_{AN})
Silicon dosage; g Si·ha^{-1}				
23.25 g	15.74 ± 1.69 a	117.4 ± 8.9 a	90.11 ± 6.69 a	1.30 ± 0.09 a
46.50 g	15.53 ± 1.71 a	115.4 ± 7.1 a	88.37 ± 7.52 a	1.31 ± 0.12 a
Time of silicon application				
BBCH 14–16	15.72 ± 1.54 a	113.7 ± 7.8 b	90.61 ± 7.61 a	1.26 ± 0.10 a
BBCH 40–41	15.66 ± 1.66 a	116.5 ± 8.5 ab	89.00 ± 7.12 a	1.31 ± 0.10 a
BBCH 14–16 and BBCH 40–41	15.53 ± 1.94 a	119.0 ± 7.4 a	88.11 ± 6.72 a	1.36 ± 0.09 a

BBCH 14–16, leaf development stage; BBCH 40–41, tuber initiation stage; BBCH 14–16 and BBCH 40–41, leaf development and tuber initiation stages. Means indicated with the same letters do not differ significantly at $p \leq 0.05$.

The nutritional compound content in new potato tubers depended on the weather conditions during potato growth (Tables 6 and 7). Regardless of the treatment (with or without silicon), the most dry matter, starch, crude protein, L-ascorbic acid and nitrates were found in the tested potato tubers in 2018, which was warm and very dry, whereas the most total sugars were found in 2016, with periodic water deficits. The hydrothermal conditions during the potato growth period slightly affected the monosaccharide accumulation in tubers.

Table 6. Effects of weather conditions on dry matter and carbohydrate content; mean ± standard deviation.

Years	Dry Matter % FW	Starch $g \cdot kg^{-1}$ FW	Total Sugars $g \cdot kg^{-1}$ FW	Monosaccharides $g \cdot kg^{-1}$ FW
2016	17.61 ± 0.82 b	112.9 ± 5.37 b	6.74 ± 0.39 a	1.95 ± 0.22 a
2017	16.46 ± 1.05 c	106.4 ± 4.68 c	6.20 ± 0.47 b	2.15 ± 0.28 a
2018	22.32 ± 0.83 a	142.4 ± 7.47 a	6.61 ± 0.27 a	2.20 ± 0.20 a

Means indicated with the same letters do not differ significantly at $p \leq 0.05$.

Table 7. Effects of weather conditions on protein, L-ascorbic acid and nitrate content; mean ± standard deviation.

Years	Protein $g \cdot kg^{-1}$ FW	L-Ascorbic Acid $mg \cdot kg^{-1}$ FW	Nitrates $mg \cdot kg^{-1}$ FW	Ascorbate-Nitrate Index (I_{AN})
2016	15.43 ± 0.81 b	117.3 ± 5.09 a	87.8 ± 6.96 b	1.34 ± 0.13 a
2017	14.02 ± 0.91 c	110.5 ± 4.91 b	85.5 ± 4.98 b	1.30 ± 0.10 a
2018	17.27 ± 1.21 a	121.5 ± 2.44 a	95.8 ± 4.35 a	1.27 ± 0.07 a

Means indicated with the same letters do not differ significantly at $p \leq 0.05$.

3.3. Darkening of Cooked Potatoes

Silicon had no effect on the color of tuber flesh after cooking (Table 8). The dosage and time of silicon application slightly affected the color of tuber flesh directly after cooking and 2 h after cooking (Table 9).

Table 8. Effects of silicon (Si) on darkening of cooked potatoes; mean ± standard deviation.

Treatment	After-Cooking Darkening; 9-Point Danish Scale	
	10 min after Cooking	2 h after Cooking
Control	8.97 ± 0.05 a	8.87 ± 0.04 a
With Si	8.94 ± 0.07 a	8.85 ± 0.06 a

Means indicated with the same letters do not differ significantly at $p \leq 0.05$.

Table 9. Effects of dosage and time of silicon (Si) application on darkening of cooked potatoes; mean ± standard deviation.

Dosage and Time of Silicon Application	After-Cooking Darkening; 9-Point Danish Scale	
	10 min after Cooking	2 h after Cooking
Silicon dosage; g $Si \cdot ha^{-1}$		
23.25 g	8.96 ± 0.06 a	8.87 ± 0.07 a
46.50 g	8.92 ± 0.08 a	8.83 ± 0.12 a
Time of silicon application		
BBCH 14–16	8.94 ± 0.06 a	8.85 ± 0.08 a
BBCH 40–41	8.94 ± 0.07 a	8.86 ± 0.09 a
BBCH 14–16 and BBCH 40–41	8.93 ± 0.08 a	8.83 ± 0.12 a

BBCH 14–16, leaf development stage; BBCH 40–41, tuber initiation stage; BBCH 14–16 and BBCH 40–41, leaf development and tuber initiation stages. Means indicated with the same letters do not differ significantly at $p \leq 0.05$.

The discoloration of cooked potatoes depended on the weather conditions during the potato growth period. The greatest darkening was observed in 2016, a warm period with periodic water deficits (Table 10).

Table 10. Effects of weather conditions on darkening of cooked potatoes; mean ± standard deviation.

Years	After-Cooking Darkening; 9-Point Danish Scale	
	10 min after Cooking	2 h after Cooking
2016	8.92 ±0.07 a	8.82 ± 0.09 b
2017	8.96 ± 0.06 a	8.89 ± 0.05 a
2018	8.94 ± 0.08 a	8.85 ± 0.08 ab

Means indicated with the same letters do not differ significantly at $p \leq 0.05$.

4. Discussion

Good conditions for potato growth must be ensured to obtain a high-commercial-value product at an early harvest time. In sustainable potato production, biostimulants have been gaining increasing importance as a low-input tool to mitigate environmental stresses and improve plant growth [17]. In recent years, the application of silicon has been increasing as a plant growth stimulant. In the present study, foliar silicon (sodium silicate) application improved plant growth and increased the yield of new potatoes under a water deficit [31,35] but slightly affected their nutritional value. Early-harvested potatoes contain low dry matter, which results in a soggy texture and decreases their nutritional value. In the present study, a single or a double silicon (sodium silicate) application at 23.25 g Si·ha^{-1} or 46.50 g Si·ha^{-1} (0.25 L·ha^{-1} or 0.50 L·ha^{-1} of Optysil) did not affect the dry matter content tubers of the very early cultivar Catania. In Brazil, three sprays of stabilized silicic acid (1.425 mM Si water solution) had no effect on the dry matter content in tubers of very early cultivar Agata under greenhouse conditions [29], whereas, under uncontroled field conditions, stabilized silicic acid (2 dm^3·ha^{-1} of a commercial product containing 0.8% of soluble Si) increased or decreased the dry matter accumulation by tubers of the Agata cultivar depending on the environmental conditions, but had no effect on the dry matter content in tubers of the late cultivar Atlantic [32]. Previously, field experiments in Poland showed that one to three applications of orthosilicic acid (Krzemian at 0.8 dm^3·ha^{-1}) caused an increase in the dry matter content in tubers of the medium–early cultivar Oberon [34], but three sprays of orthosilicic acid (0.3 dm^3·ha^{-1} or 0.4 dm^3·ha^{-1} of Actisil) had no effect on the dry matter accumulation by tubers of the medium–late cultivar Jelly [36]. This suggests that silicon's effect on the dry matter accumulation by potato tubers depends on its source, the cultivar and the plant growth conditions. The dry matter accumulation by potato tubers is influenced by the assimilation leaf area and photosynthetic pigment content. According to Sawicka et al. [13], reducing the assimilation area and increasing the chlorophyll *a* content in leaves results in an increase in the dry matter content in tubers. In the present study, silicon caused the enlargement of the assimilation area and an increase in chlorophyll content in the leaves of very early cultivar Catanc conditions [51] but did not affect the dry matter content in tubers.

The carbohydrate content, especially starch, is one of the main quality traits of edible potatoes. In the present study, silicon (sodium silicate) caused an increase in starch content in tubers of the very early potato Catania under a water deficit but did not affect the total sugar and monosaccharide content. Under drought stress (2018 season), following silicon application, the starch content in tubers 75 days after planting was higher by 14.5 g·kg^{-1} FW than in the untreated control tubers. The starch accumulation by tubers was most stimulated by silicon application at 46.50 g Si·ha^{-1} (0.50 L·ha^{-1} of Otysil) in the leaf development stage (BBCH 14–16). Previously, a study showed also an increase in the starch content in tubers of medium–early cultivar Oberon following the application of orthosilicic acid (Krzemian) [34]. The starch content in potato tubers depends on the assimilation area and chlorophyll *a* content in leaves, as well as the photosynthetic capacity of PS II in the dark. Reducing the assimilation area and photosynthetic capacity results in a reduction in the starch content in tubers [13]. One of the possible mechanisms of the Si-induced mitigation of abiotic stress in plants is improved photosynthesis and protection of photosynthetic pigments by degradation, which may be associated with the increased activities of some antioxidant enzymes (superoxide dismutase SOD, catalase CAT) located in the chloroplast and with the regulation of photosynthesis-related gene expression [20,52]. In the present study, enlargement of the assimilation area and chlorophyll content in leaves under Optysil application [51] resulted in an increase in starch content in tubers but did not affect the sugar content. The Si-based biostimulant Optysil contains also iron chelate (Fe-EDTA). Iron is a cofactor of most antioxidant enzymes and it is required for photosynthesis and chlorophyll synthesis [53]. The sugar content is associated with the tuber's physiological age [54].

Previous studies showed that orthosilicic acid caused an increase in the vitamin C content in tubers of the medium–early cultivar Oberon [34] and a reduction in the nitrate content in tubers of the medium–late cultivar Jelly [36]. In the present study, sodium silicate did not affect the content of protein or L-ascorbic acid and only slightly decreased the nitrate amount in tubers of the very early cultivar Catania. The positive effect of silicon on the nitrate reduction may be related to the regulation of nitrogen metabolism enzymes' activity [18]. Trawczyński and Wierzbicka [55] indicated a relationship between vitamin C and the nitrate content in potatoes from different groups of maturity. A higher amount of vitamin C is accompanied by a lower nitrate amount. The ratio of ascorbic acid/nitrate is an indicator of vegetables' safety regarding the nitrate content. A higher ascorbate nitrate index (I_{AN}) reflects higher safety for human health [49]. In general, new potatoes have been connected with high nitrate levels. According to Ierna [56], the relationship between the nitrate concentration and tuber maturity is not clear and differs between cultivars. The I_{AN} for the new potatoes tested was approximately 1.3/1. The L_{AN} value 0.5–1 indicates that vegetables are harmless to human health regarding nitrate content, while >1 indicates that they are absolutely safe [49].

New potatoes are appreciated for their freshness and nutritional value. The nutrient content in the new potatoes tested depended on the weather conditions during potato growth to a greater extent than on the silicon applied. Sugar metabolism in potato is regulated by physiological and environmental factors. The main factor affecting the conversion of sucrose to starch is the activity of sucrose synthase (SuSy) and ADP-glucose phyrophosphorylase (ADP). Tuber maturity, temperature and soil moisture are the factors affecting the sugar content in tubers [4,57,58]. Nitrate accumulation in plants is more affected by the weather conditions than by the form and dosage of nitrogen [54]. According to Trawczyński [6], the starch content in potato tubers is mainly cultivar-dependent, the amount of nitrates is determined by the weather conditions during the potato growth period, and the amounts of vitamin C and protein are dependent on the interaction of cultivars and weather conditions. Potato tubers grown under water deficit conditions contained more dry matter, starch, protein and ascorbic acid [6,59], which was confirmed in the present study.

The darkening of tuber flesh after cooking is an important sensory characteristic of edible potatoes. In the present study, silicon did not affect the color of tuber flesh after the cooking of very early cultivar Catania. Previous studies showed no effect of orthosilicic acid (Krzemian) on the darkening of raw tubers of the medium–early cultivar Oberon [34]. According to Hussain et al. [11], the effect of management practices on the discoloration of cooked potatoes is smaller than the effect of the cultivar and weather conditions during potato growth, which was confirmed in the present study.

5. Conclusions

The results of the current study showed that foliar silicon (sodium silicate) application to improve the growth of early crop potatoes slightly affected the nutritional value and sensory quality of new potatoes. Silicon had no effect on the dry matter, total sugars and monosaccharides, protein, L-ascorbic acid or nitrate content in tubers 75 days after planting but only increased the starch accumulation under water deficit conditions. The most starch was accumulated by tubers following the application of 46.50 g Si·ha^{-1} (0.50 L·ha^{-1} of Optysil) at the leaf development stage (BBCH 14–16). Silicon did not affect the color of tuber flesh after cooking. The nutrient content and sensory quality of new potatoes depended to a greater extent on the weather conditions during potato growth. Since the growth period of early crop potatoes is short, future studies are necessary to evaluate the effect of silicon on the tuber yields and quality of various potato cultivars and develop recommendations for farmers.

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