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THE EFFECT OF SILICON APPLICATION ON GROWTH OF SPRING WHEAT UNDER ORGANIC FARMING

Summary

Application of silicon (Si) could greatly boost wheat yield and mitigate abiotic stress, especially drought. A field experiment was conducted during 2017- 2018 at the research farm. Evaluation of impact of different methods of application of two Si fertilizers on growth and parameters of yielding of wheat was made. The treatments consisted of the recommended dose of two used Si fertilizers – Adesil and ZumSil at 10 kg and 0,3 l·ha^{-1}, respectively. Spring wheat cv. Arabella was used in the field experiments. The effect of silicon was assessed by measuring emergence, height of plants, density of spikes and the SPAD index. The number of plants emergence, the height of plants and density of spikes · 1m^{-2} were the highest after application of liquid ZumSil, regardless of the method of application. The study revealed a significant effect of silicon on plant.
***Key words**: plant height, growth, SPAD, yield*

WPŁYW STOSOWANIA KRZEMU NA WZROST PSZENICY JAREJ W SYSTEMIE ROLNICTWA EKOLOGICZNEGO

Streszczenie

Zastosowanie krzemu (Si) może znacznie zwiększyć plony pszenicy i złagodzić stres abiotyczny, zwłaszcza suszę. Doświadczenie polowe przeprowadzono w latach 2017-2018 w gospodarstwie badawczym. Dokonano oceny wpływu różnych, trzech metod stosowania dwóch nawozów Si na parametry wzrostu i plonowanie pszenicy. Zabiegi obejmowały zalecaną dawkę dwóch różnych nawozów krzemowych stosowanych osobno - Adesil i ZumSil w dawce 10 kg i 0,3 l·ha^{-1}, odpowiednio. W doświadczeniach polowych wykorzystano pszenicę jarą, odm Arabella. Wpływ nawozów w okresie wegetacji rośliny oceniano pod kątem ich wschodów, wysokości roślin i obsady kłosów. Liczba wschodów, wysokość roślin i obsada kłosów na ·m^{-2} były najwyższe po zastosowaniu płynnego ZumSil, niezależnie od metody aplikacji. Obserwacje potwierdziły znaczący wpływ krzemu na rośliny.
***Słowa kluczowe**: wysokość roślin, rozwój roślin, SPAD, plon*

1. Introduction

Many adverse environmental factors for plants production may be mitigated by using bio-stimulators, i.e. preparations that stimulate plant processes and trigger the mechanisms that enable plant functioning under stress and increase quantity and quality of yield. The silicon content included in fertilizers or/and in biostimulators might be used in organic and sustainable crop production and is critical to plants' defense against pests and diseases as well as environmental stresses. Hence, improved Si management to increase yield and sustain crop productivity appears to be necessary. The literature on silicon (Si) and its influence on plants shows that this element promotes plant growth, may stimulate plant growth and development and reduce the threat of pathogen and pest infestation because silicon is needed by plants to grow strong cell walls [11]. In most cases however, it is uncertain whether growth stimulation is attributable to a nutritional effect or to the alleviation of biotic or abiotic stresses [4, 9]. The formulations available on the market differ in their mechanisms of action, technological purpose and origin [1, 2, 14].

Silicon is the second most abundant element after oxygen in soil: silicon dioxide comprises 50-70% of the soil mass. As a consequence, all plants rooting in soil contain some Si in their tissues. However, the role of Si in plant growth and development was overlooked. All plants need some silicon in the form of monosilicic acid in the soil to thrive. All soils have a lot of silicon present, sandy soils more than clays, but most is in the form of silicon dioxide which is insoluble and not available to plant. Many soils do not have enough monosilicic acid present to match the plants requirements [14]. Silicon fertilizer has a double effect on the soil–plant system as under (i) Improved plant-silicon nutrition reinforces plant-protective properties against diseases, insect attack, and unfavorable climatic conditions. (ii) Soil treatment with biogeochemically active silicon substances optimizes soil fertility through improved water, physical and chemical soil properties, and maintenance of nutrients in plant-available forms. The ability of soluble silicon (Si) can also reduce the impact of plant diseases [11, 13].

The aim of the study includes evaluation of impact on growth and yield of spring wheat of two silicon fertilizers approved to organic farming applied by different methods.

2. Materials and methods

The study was conducted in the years 2017-2018 (spikes were collected only in 2017), at the field managed under organic farming conditions at the Research Farm of IPP-NRI. In the field, the conditions were changed due to changing seasons. From April until middle July were noted different conditions of weather, average values are included in Table 1.

Table 1. Mean values of temperature and humidity during the experiments

Tab. 1. Średnie wartości temperatury i wilgotności w czasie trwania eksperymentów

Month/year	Temp. [^{0}C]	RH [%]
April (2017-2018)	13,7	70,2
May (2017-2018)	17,5	66,6
June (2017-2018)	19,1	68,4
July (2017)	20,2	58,4

Source: own work / Źródło: opracowanie własne

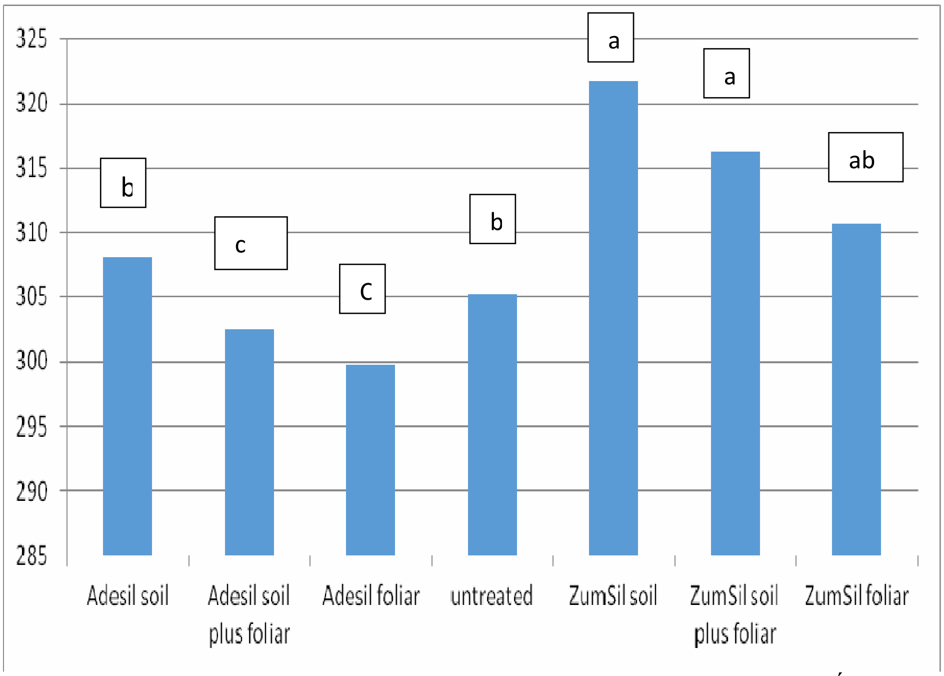
The experiment was set as a big block with indicated eight points where evaluated plants were located across the whole big plot. Two silicon products were used, AdeSil^R as powder formulation at dose 10 kg·ha^{-1} and ZumiSil^{TM} as liquid at dose 0,3 l·ha^{-1}. According to information of producer ZumSil^{TM} is the perfect plant and soil amendment. ZumSil is a 24% solution of monosilicic acid. AdeSil^R it is a powder formulation on the basis of diatomaceous earth. In this study different (3) methods of applications were used, each product was applied separately in way: (1) only one application before sowing, directly to the soil, (2) the foliar application only, (3) combined soil and foliar treatments. The first foliar spraying was at BBCH 23-25, the next one was carried out at stem elongation phase, the last was at BBCH 61 (start blooming). The experiment was performed using "Arabella" cultivar. These fertilizers considered as an anti-stress product distributed in Poland by Perma-Guard ^{TM}. During the field experiment were assessed: i) emergence, ii) plant height in different development stages, iii) SPAD values in different stages, iv) number of spikes. Number of emergences · m^{-2} was evaluated at stage BBCH 21 (beginning of tillering) at each point of evaluation; height of plants was evaluated at BBCH 21, BBCH 39 and BBCH 75 as measures of 50 plants collected from whole big plot within one treatment. SPAD chlorophyll index was measured four times at BBCH 31, BBCH 32, BBCH 51 and BBCH 75, in each combination on big plot were set 8 locations and at every location 5 plants were tested using the SPAD-502 chlorophyll meter (Minolta Camera Co., Japan). Number of spikes·m^{-2} was evaluated at BBCH 75 as spikes collected from 3 points on whole big plot. All the results were subject to a variance analysis and the significance of differences was verified by Tukey's test at the level $p \leq 0.05$.

3. Results

Generally, it was confirmed that treatments with silicon had rather positive effect on growth and yielding of spring wheat. The highest number of emergence was obtained on the area where ZumSil was applied, regardless of method of application. However, the best effect was obtained after application of ZumSil before sowing, directly to the soil and in combined treatments (Fig. 1).

More differences between effects of fertilizers were observed at late stage of development, at BBCH 75 it was noted that the highest plants were observed on plots treated by ZumSil, regardless of method application (Fig. 2). According to literature Si fertilization resulted in leaf chlorophyll content. Values of SPAD obtained after Si fertilization were more frequently higher compared to values of SPAD from untreated plants. Furthermore, differences in this parameter were observed depending on the time of measurement, as its values were the highest at the earing formation stage, however differences were not statistically important (Table 2).

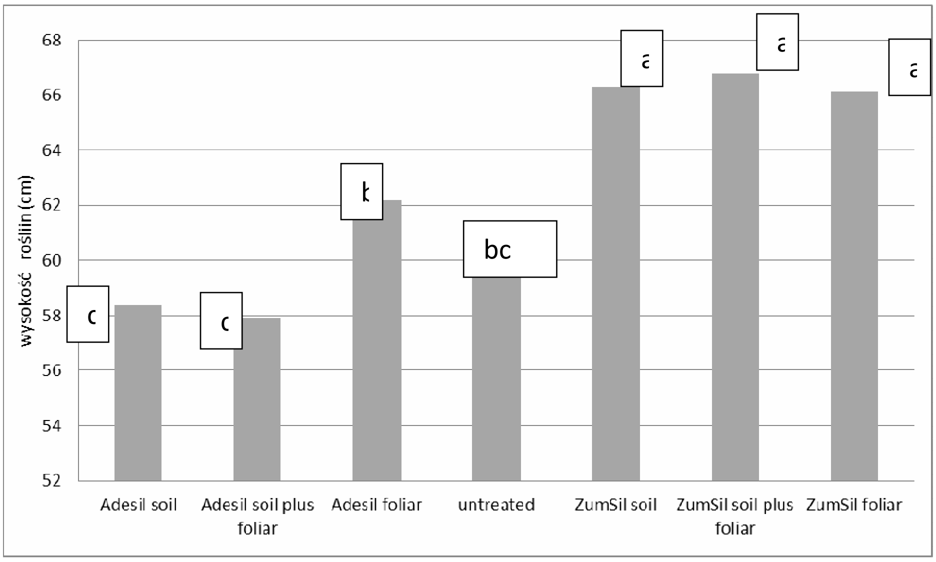
Height of treated plants at BBCH 21 and BBCH 39 was higher compared to untreated, it is clear indicated after application of ZumSil regardless of methods of application (Table 3). Similar effect was observed only when Adesil was applied as combined treatments (Table 3).



Source: own work / Źródło: opracowanie własne

Fig. 1. Mean number of emergences per 1 m^2 at stage BBCH 32

Rys. 1. Średnie wartości wschodów na 1 m kwadratowym w fazie rozwojowej BBCH 32 (drugie kolanko)



Source: own work / Źródło: opracowanie własne

Fig. 2. Effect of different silicon fertilizers and methods of application on mean height of plants at BBCH 75
Rys. 2. Efekt różnych form nawożenia krzemem i metod nawożenia na wysokość roślin w fazie 75 (dojrzałość mleczna ziarniaków)

Table 2. Effect of different Si fertilizations and methods of application on values of SPAD
Tab. 2. Efekt różnych form nawożenia i metod ich aplikacji na wartości SPAD

	BBCH 31 second knot	BBCH 32 second knot	BBCH 51 earing formation	BBCH 75 milk grain maturity
Adesil soil	32,5	36,4	47,2	46,3
Adesil soil plus foliar	33,8	37,5	47,9	45,2
Adesil foliar	32,9	35,1	46,5	44,9
untreated	32,4	34,6	44,3	43,4
ZumSil soil	33,1	33,9	45,5	43,9
ZumSil soil plus foliar	31,9	34,2	48,5	40,6
ZumSil foliar	32,5	34,4	46,3	33,0

All data are ns - non statistically different *Source: own work / Źródło: opracowanie własne*

Table 3. Mean height of plants depending on Si fertilization
Tab. 3. Średnia wysokość roślin w zależności od nawożenia krzemem

	BBCH 21 beginning of tillering [cm]	BBCH 39 flag leaf [cm]
Adesil soil	15,05	49,3 b
Adesil soil plus foliar	14,4	49,7 ab
Adesil foliar	14	49 b
untreated	13,6	43,9 c
ZumSil soil	14,65	**51 a**
ZumSil soil plus foliar	14,35	**51,6 a**
ZumSil foliar	13,95	**51,1 a**

Source: own work / Źródło: opracowanie własne

Similarly, like at case of height of plants, high mean number of spikes was noted on plot where ZumSil was applied, regardless of method of application (Table 4). Also, higher mean number of spikes was observed on plots where Adesill was applied as combined treatments (Table 4).

The highest number of spikes was recorded in combination, where both fertilizers were used both to the soil and as foliar spraying (464 and 478 ears, respectively for Adesil and ZumSil). ZumSil increased number of spikes even when was applied as simply treatment. In all combinations where fertilization was done, statistically significant spike density was obtained compared to the control (374/m^2), except where Adesil was applied before sowing (Table 4).

Table 4. Effect of different silicon fertilizations and methods of application on mean number of spikes as parameter of yielding
Tab. 4. Efekt różnych form nawożenia krzemem i różnych metod aplikacji na średnią obsadę kłosów na 1 m^2

Methods of application	Mean number of spikes · 1 m^{-2} at BBCH 75
Adesil soil	393,25 bc
Adesil soil plus foliar	**464,75 a**
Adesil foliar	431,75 bd
untreated	374 c
ZumSil soil	**453,75 a**
ZumSil soil plus foliar	**478,5 a**
ZumSil foliar	**462 a**

$p \leq 0,05$ *Source: own work / Źródło: opracowanie własne*

4. Discussion

The effects of silicon on crops such as vegetables, fruit trees and shrubs, rape, wheat, potato, corn and meadow plants have been investigated also in Poland [5, 10]. The SPAD chlorophyll meter is useful for rapid analysis of chlorophyll and nitrogen status of crops, while it has not been established how strongly the meter readings are correlated with fertilization and different fertilizer management options. Our results indicated that silicon fertilization had rather positive influence for development and yielding of spring wheat. In this crop is very limited research about silicon. In presented work, SPAD index was different depending on the time of measurement, as its values were the highest at earing formation. This effect is in line with other research conclusions obtained by Radkowski and Radkowska, who noted the highest SPAD at the flowering stage [11]. Ahmad et al., who investigated the role of silicon in fertilization of wheat (*Triticum aestivum* L.) under different soil humidity conditions, reported that silicon application considerably improved plant biomass, height and ear weight [2]. Our results are confirming theirs results.

In other trials, Si amendment, either through the roots or the leaves, did not increase plant growth. Also the research conducted by Segalin et al. [13] revealed that foliar application of silicon did not affect either yield or physiological quality of wheat seeds of different cultivars. We conclude that combined – foliar and to the soil – methods were the most effective for growth of wheat. This statement is similar like concluded Guevel et al. [6]. Thus, the yield response to Si may be related to an improved uptake of this nutrient [7] and methods of delivery them to plants.

5. Conclusions

The results of the field experiment showed the beneficial effect of using the silicon fertilizers. During the study, relative chlorophyll content, expressed as the leaf greenness index (SPAD) was found to increase until earing formation. Plants treated by silicon were better developed. Higher incidence of emergence, height of plants and density of spikes were found in treated plots where ZumSil was applied. No differences between effectiveness of ZumSil in relation to methods of application were noted.

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