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The effect of biostimulators on the yield and quality of potato tubers grown in drought and high temperature conditions

Wpływ biostymulatorów na plon i jakość bulw ziemniaka uprawianego w warunkach suszy i wysokiej temperatury

Cezary Trawczyński

Zakład Agronomii Ziemniaka, Instytut Hodowli i Aklimatyzacji Roślin – Państwowy Instytut Badawczy, Oddział w Jadwisinie,
✉ c.trawczynski@ihar.edu.pl

In the years 2018 – 2019, field trials were carried out on light soil on the effect of foliar fertilization of potato plants with biostimulators: Krzemian (silicon preparation), Naturamin Plus and Naturamin WSP (amino acid preparations) with regard to the yield and quality of potato tubers. Each year, two foliar fertilization treatments were carried in BBCH 19 and 39 phases - Naturamin Plus and Naturamin WSP preparations, and 39 and 70 – silicate preparation. The control was without foliar fertilization, water being used instead. The soil was amended each year by incorporating through ploughing, straw from winter triticale and green intercrop from white mustard, while mineral fertilization was applied in the following doses: 100 kg·ha^{-1} N, 26.2 kg·ha^{-1} P and 99.6 kg·ha^{-1} K. Under the influence of the preparations used in the studies, a similar increase in tuber yield was obtained, higher by 17.3% compared to the control. A greater increase in tuber yield under the influence of preparations was obtained in the year of 2018, with less rainfall deficiency and higher air temperature than in the year of 2019. Under the influence of the preparations used, a significant increase in the content of starch, dry matter and vitamin C in tubers was obtained, but the preparation of Krzemian caused a decrease in the level of nitrates (V) in tubers, compared to the control.

Key words: biostimulators, quality of tubers, yield, weather conditions, potato

W latach 2018 – 2019 przeprowadzono na glebie lekkiej badania polowe nad określeniem wpływu dolistnego dokarmiania roślin ziemniaka biostymulatorami: Krzemian (preparat krzemowy), Naturamin Plus i Naturamin WSP (preparaty aminokwasowe) na plon i jakość bulw ziemniaka. W każdym roku wykonywano dwa zabiegi dolistnego dokarmiania w fazach BBCH 19 i 39 (preparatami Naturamin Plus i Naturamin WSP) oraz 39 i 70 (preparatem Krzemian). Kontrolę stanowił obiekt bez dolistnego dokarmiania i stosowania wody. Nawożenie organiczne stanowiły przyorywane każdego roku: słoma z pszenżyta ozimego i zielona masa międzyplonu z gorczycy białej. Nawożenie mineralne stosowano w dawkach: 100 kg·ha^{-1} N, 26,2 kg·ha^{-1} P i 99,6 kg·ha^{-1} K. Pod wpływem zastosowanych preparatów uzyskano w badaniach zbliżony przyrost plonu bulw, większy o 17,3% w porównaniu do kontroli. Większy przyrost plonu bulw pod wpływem preparatów uzyskano w 2018 roku, o mniejszym niedoborze opadów i wyższej temperaturze powietrza, niż w 2019 roku. Pod wpływem zastosowanych preparatów uzyskano istotny wzrost zawartości skrobi, suchej masy i witaminy C w bulwach, a preparat Krzemian spowodował obniżenie poziomu azotanów (V) w bulwach w porównaniu do obiektu kontrolnego.

Słowa kluczowe: biostymulatory, jakość bulw, plon, warunki pogodowe, ziemniak

Introduction

Prevention of the negative effects of weather on the growth of plants and activation of natural defence mechanisms stimulating plant growth and development should be the foundation of prophylactic measures in modern environmentally-friendly potato production technologies (Rykaczewska 2013, Sharma et al. 2014). One way to improve the health of plants grown under unfavourable weather conditions, and thus to obtain a sufficiently high tuber yield and quality, may be foliar feeding of plants with products containing bioactive compounds and quickly assimilable forms of nutrients (Erlichowski and Pawińska 2003, Trawczyński 2013, Wierzbowska et al. 2015). For this reason, biostimulants are attracting the increasing interest of farmers growing various crops, including potatoes. Because of origin and various production technologies, biostimulants were recently categorised into several classes (Du Jardin 2015). Due to the technological diversity and the presence of various bioactive elements and substances in their composition, these products may elicit different effects on individual plants species. This means that their effect may be positive in some

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species, but not in others, which may result from the sensitivity of plants to specific bioactive molecules (Ertani et al. 2011). Therefore, the increasingly wider range of biostimulants emerging on the market prompted us to evaluate them, especially those with declared specific and comprehensive activity or containing elements with undefined properties. One category of these products comprises protein hydrolysate-based biostimulants (Colla et al. 2015). They can stimulate the growth of the above-ground organs and the root system, the synthesis of chlorophyll, the uptake of nutrients from the soil or the metabolism of basic elements (Popko et al. 2018). Among the elements, the biostimulating effect on various species of crops was demonstrated for certain forms of silicon (Mitani and Ma 2005, Raven 2003). In soil, silicon exists in the form of non-assimilable silica, but when applied on plants in a liquid formulation, e.g. orthosilicic acid, it can impregnate the external epidermal cells, strengthen cell walls, and increase their rigidity and resistance to physical damage (Sommer et al. 2006). A thicker cuticle saturated with silicon may reduce the loss of water and make plants less affected by fungal diseases and pests (Fauteuxi et al. 2005, Romero-Aranda et al. 2006, Sacała 2009). Previous studies have confirmed the beneficial effect of different silicon products on the yield and quality of dicotyledons, including root crops (Artyszak et al. 2016) and vegetables (Górecki and Danielski-Busch 2009, Stamatakis et al. 2003, Ugrinović et al. 2011), which prompted us to conduct relevant research on potatoes. Additionally, in reference to the above arguments, the strong correlation between the yield and quality of potato tubers and weather conditions stimulated the need for specific studies, especially in crops grown under extreme weather conditions.

Therefore, the aim of our research was to assess the effect of amino acid biostimulants and silicon on the yield and quality of potato tubers grown in drought and high temperatures.

Material and Methods

The field research was carried out in 2018-2019 at the IHAR-PIB department in Jadwisin (52°45’ N, 21°63’ E) on clay-illuvial soil, luvisol type, stagnic luvisol subtype (Marcinek et al. 2011). The soil was acidic, with a high content of available phosphorus, moderate content of potassium, manganese, zinc, copper and boron, and low content of magnesium (Table 1).

The experiment was established in a random block system in three replicates. The size of a single plot was 18.6 m^2. The following biostimulating products were used in the study: Krzemian, containing silicon and microelements, and Naturamin Plus and Naturamin WSP, containing amino acids from protein-rich plants. Amino acid biostimulants (Naturamin Plus and Naturamin WSP) were applied on potato plants at stage BBCH 19 (9 or more leaves of main stem unfolded) and BBCH 39 (crop cover complete: about 90% of plants meet between rows), and Krzemian was applied at stages BBCH 39 and 70 (flowering complete, first berries visible). The combination of treatments was as follows: 1. Control plot – no foliar feeding and watering, 2. Krzemian – 0.8 $l \cdot ha^{-1}$, 3. Naturamin Plus – 1.5 $l \cdot ha^{-1}$, 4. Naturamin WSP – 0.5 $kg \cdot ha^{-1}$.

Composition of products used in the experiment:

Krzemian – Si(OH) 4– 2.5%; Cu – 1.0%; Zn – 0.6%; B – 0.3%; Mo – 0.2%

Naturamin Plus – free amino acids – 32%; N – 6%; Fe – 1%; Mn – 0.6%; Zn – 0.2%; B – 0.1%; Cu – 0.1%; Mo – 0.047%

Naturamin WSP – free amino acids – 80%; N – 12.8%.

Biostimulants for each treatment were dissolved in 300 $l \cdot ha^{-1}$ water.

Weather conditions during the growing season were assessed based on the sum of rainfall and mean air temperatures, and compared to multiannual sums of rainfall and mean air temperatures. In 2018, all months of vegetation were characterized by rainfall below the multiannual sum, and air temperature was significantly higher than the multiannual mean. The total rainfall for the entire growing season in 2018 was 79.2 mm lower, and the mean air temperature was 3.5°C higher than the corresponding

Tabela 1
Table 1

Właściwości chemiczne gleby przed założeniem doświadczenia
Soil chemical properties before planting of experiment

Lata Years	C organiczny % C organic %	pH w KCl pH in KCl	Zawartość $mg \cdot kg^{-1}$ / Content $mg \cdot kg^{-1}$						
			P	K	Mg	Mn	Cu	Zn	B
2018	0,88	5,4	84	104	26	118	4,0	4,3	1,32
2019	0,66	5,2	75	100	22	91	5,2	4,9	0,94

multiannual mean values. Based on the weather conditions, 2018 was defined as a dry and very warm year. On the other hand, in 2019, in the main months of the growing season, the shortage of rainfall was greater than in 2018 and the air temperature was higher than the multiannual mean value. The deficit of rainfall for the entire growing season in 2019 was 135.6 mm, and the air temperature was 2.3°C higher than the multiannual mean. Therefore, 2019 was defined as a very dry and warm year (Table 2).

Soil was amended by ploughing in shredded winter triticale straw (about 5 t·ha^{-1} with the addition of 1 kg N per 100 kg of straw) after harvest, and green biomass from white mustard stubble intercrop (15–16 t·ha^{-1}) in autumn. Mineral fertilization with phosphorus (fortified superphosphate 17.4% P) and potassium (potassium salt 49.8%-K) relevant to the content of available forms of these components in the soil was applied in early spring before the start of cultivation at a dose of 26.2 kg P·ha^{-1} and 99.6 kg K·ha^{-1}. Mineral fertilization with nitrogen (calcium ammonium nitrate-27% N) was applied at a dose of 100 kg N·ha^{-1} in the spring before planting tubers.

Weeds were destroyed twice by using a hiller before the emergence of potato plants. Directly before emergence, after the last hilling, Linurex 500 SC was applied at a dose of 2 l·ha^{-1} (in 2018) and Proman 500 SC at a dose of 4 l·ha^{-1} (in 2019), and after the emergence of plants in both years Titus 23 WG at a dose of 60 g·ha^{-1}. During the growing season, plants were treated against potato blight: three times in 2018 and two times in 2019. Treatments against the Colorado beetle were also used: four times in 2018, and five times in 2019.

Potatoes (Oberon cultivar) were planted by hand in the last ten days of April, spaced 75 x 33 cm, and harvested in the last ten days of September. There were 75 plants per plot. During harvest, the total yield of tubers from each plot was estimated and two 5-kilogram samples were taken to assess the yield structure, and the weight of tuber fractions with a diameter of: less than 35 mm, 36 – 50 mm, 51 – 60 mm and more than 60 mm (Regulation 2003), the share of tubers with defective appearance in the yield (deformed, with greenings, infected with common scab), and the chemical composition of tubers was analysed for the content of starch, nitrates, vitamin C and dry matter. The starch content was determined by the Evers method (starch hydrolysis in a boiling water bath, followed by the precipitation of protein with phosphotungstic acid) using an automatic Polamat S polarimeter. Nitrates NO_3 (V) were determined by the Griess method (with a mixture of zinc and manganese to reduce nitrates to nitrites) and the content was measured using a RQ Flex Merck reflectomer. Vitamin C content was determined as the sum of L-ascorbic and dehydroascorbic acids by Tillman's method and titration with a solution of *2,6*-dichlorophenolindophenol. The content of dry matter was determined using a 2-stage drying method, at temperatures of 60 and 105°C.

Results from tests were statistically processed using the analysis of variance. Means were compared using Tukey's test at a significance level of p=0.05. In order to determine the sources of variance of the studied parameters in the total variance, the variance components were estimated using ANOVA software. Variance components were analysed to assess the effect of biostimulants and the study years, as well as their interaction on the variance of yield and quality characteristics of potato tubers.

Results and Discussion

Tabela 2
Table 2

Warunki pogodowe w latach badań na podstawie stacji meteorologicznej w Jadwisinie

Weather conditions in the investigation years on the base meteorological station in Jadwisin

Year Rok	Miesiąc / Month						Suma / Średnia Sum / Mean
	IV	V	VI	VII	VIII	IX	
Suma opadów (mm) / Sum of rainfalls (mm)							
2018	21,7	43,4	41,0	75,2	60,6	30,9	272,8
2019	1,7	76,6	6,9	33,4	37,0	60,8	216,4
1967-2017	37,0	57,0	75,0	76,0	61,0	48,0	352,0
Średnia temperatura powietrza (°C) / Mean air temperature (°C)							
2018	13,2	17,6	19,1	21,2	20,8	15,8	18,0
2019	10,2	13,4	22,7	18,8	20,8	14,7	16,8
1967-2017	7,9	13,7	16,6	18,5	17,9	13,2	14,5

The study revealed significant differences in tuber yield between plants treated with biostimulants and control plants (not treated with foliar fertilizer) and between years (Table 3). Regardless of the years analysed, there was an increase in the yield of tubers after treatment: 19% for Naturamin WSP, 16.9% for Krzemian, and 15.9% for Naturamin Plus, compared to the control plot. Our earlier study showed an increase in tuber yield (13.8% on average in the study years) in plants treated with Tecamin, an amino acid biostimulant (Trawczyński 2014). Other researchers also reported a positive, but much more variable (3 to 36%) effect on the yield of potato tubers after treatment with biostimulants containing amino acids obtained from various sources (Matysiak and Adamczewski 2010, Mystkowska 2017 and 2018, Prajapati et al. 2016, Röder et al. 2018, Sarhan 2011). Considering the effect of silicon, our previous study showed a 9% increase in tuber yield associated with the foliar application of marine calcite, Herbagreen Basic, containing 7.99% of Si (Trawczyński 2013). With regard to sugar beet, treatment with Herbagreen Basic was associated with a mean 21% increase in the root yield compared to the control plants (Artyszak et al. 2016). In a Dutch study, foliar application of silicic acid increased tuber yield by 6.5% compared to the control plot (Laane 2017). Crusciola et al. (2009) reported that potatoes grown during drought and treated with calcium and magnesium silicate produced 11.4% higher tuber yield compared to control plants. Ryakhovskaya et al. (2016) tested the effects of different silicon products (liquid, gel and powder) and found a 10.7 to 20.3% increase in tuber yield compared to the control plants. In a study by Wróbel (2012) treatment with the foliar silicon product Actisil did not increase the yield of potato tubers in relation to the control plants. The analysis of variance components revealed that differences in the tuber yield were mainly associated with weather conditions in the study years (91.6%), while the treatment with a biostimulant accounted only for 8.1% of variance. Similar findings with respect to tuber yield were reported by Sawicka et al. (2011). Regardless of the treatment with foliar fertilizer, a significantly higher yield of potato tubers was obtained in 2018, which was a dry and very hot year, compared to 2019, which was very dry and less hot. The difference in tuber yield between the two years was 22.9%. This indicated

Tabela 3
Table 3

Wpływ dolistnego dokarmiania na plon bulw ($t \cdot ha^{-1}$) i strukturę plonu (%)

The effect of foliar fertilization on yield of tubers ($t \cdot ha^{-1}$) and yield of structure (%)

Obiekt i lata Object and years	Plon bulw Yield of tubers	Udział frakcji bulw (mm) Share of tubers fraction (mm)			
		<35	36-50	51-60	>60
Obiekt kontrolny*	41,5 b	1 b	28 a	31 a	40 a
Krzemian	48,5 a	2 a	25 a	30 a	43 a
Naturamin Plus	48,1 a	1 b	27 a	31 a	41 a
Naturamin WSP	49,4 a	1 b	26 a	29 a	44 a
2018	52,9 a	1 b	29 a	36 a	34 b
2019	40,8 b	2 a	23 b	25 b	50 a
Obiekt kontrolny*/2018	46,6 b	1 b	29 a	36 ab	34 a
Krzemian/2018	54,8 a	2 a	29 a	33 b	36 a
Naturamin Plus/2018	54,5 a	1 b	30 a	38 a	31 a
Naturamin WSP/2018	55,8 a	1 b	27 a	37 a	35 a
Obiekt kontrolny*/2019	36,4 b	2 b	26 a	25 ab	47 b
Krzemian/2019	42,2 a	1 c	21 b	28 a	50 ba
Naturamin Plus/2019	41,6 a	3 a	22 b	25 ab	50 ba
Naturamin WSP/2019	43,1 a	3 a	22 b	21 b	54 a
Udział w wariancji całkowitej/ Share in total variance (%)					
Preparat/Formula (1)	8,1	1,4	4,2	0,7	1,4
Lata/Years (2)	91,6	70,2	91,0	95,8	97,5
(1x2)	0,3	28,4	4,8	3,5	1,1

**Control object; Średnie z tymi samymi literami nie różnią się istotnie / Means with the same letter do not differ significantly.*

that rainfall had a greater impact on the potato yield than air temperature during the growing season, which was also reported by Mystkowska (2018). Generally, a more favourable effect of foliar feeding with the tested biostimulants was achieved in the hot year, but with a lower rainfall deficit, which was reflected in an increase from 1.7 to 2.6% compared to the year with a greater shortage of rainfall and less hot weather. In general, more positive effects of biostimulants on the yield were observed in the years with unfavourable weather during the growing season, mainly caused by the excess or deficiency of rainfall and air temperature higher than the multiannual mean (Artyszak et al. 2014, Mystkowska 2018, Trawczyński 2013 and 2014). Wierzbowska et al. (2015) showed that in years with excess rainfall and high air temperature, the tuber yield in plants treated with foliar biostimulants increased on average by 20% compared to the control plot. Similarly, Cwalina-Ambroziak et al. (2015) demonstrated a positive effect of biostimulants on the yield of tubers in potatoes at risk of potato blight resulting from very wet weather.

Differences in the shares of tuber fractions were less marked than differences in the yield of tubers. Regardless of the year studied, foliar feeding with biostimulants was associated with a decrease in the share of the fraction of tubers with a diameter of 36-50 mm and an increase in the share of large tubers, with a diameter of more than 60 mm (Table 3). The analysis of interaction revealed that only in the second year of the study significantly fewer tubers size 36-50 mm were obtained from plants treated with biostimulants compared to the control plants, and significantly more large tubers with a diameter greater than 60 mm were obtained from plants treated with Naturamin WSP. However, significant differences in all tuber size fractions were found between the study years. In the first year of the study, when the rainfall deficit was lower, significantly more tubers size 36–50 mm and 51–60 mm were harvested, while in the year with a greater deficit of rainfall, there was a greater share of large tubers with a diameter larger than 60 mm. This was probably associated with a smaller number of tubers formed in a very dry year and thus the formed tubers grew to a larger size. Previous studies revealed a positive effect of foliar feeding with a silicon biostimulant on the structure of tuber yield, mainly by a significant reduction in the share of small tubers with a diameter of less than 30 mm (Wróbel 2012). On the other hand, Głosek-Sobieraj et al. (2017) reported that treatment with foliar biostimulants was associated with an increased share of 36–50 mm tubers in the yield structure, while Baranowska et al. (2019) reported an increase in the share of tubers larger than 50 mm. In our research, weather conditions in the study years also had the greatest impact on the yield structure, since weather accounted for 70.2% of total variability for small tubers with a diameter below 35 mm, and 97.5% of total variability for tubers larger than 60 mm. Use of biostimulants as a variance component had the strongest effect on the share of tubers with a diameter of 36-50 mm, and the interaction between a biostimulant and study years on tubers smaller than 35 mm.

Considering the analysed defects of tuber appearance, treatment with biostimulants was associated only with significant differences in the share of deformed tubers (Table 4). On average in both years, treatment with Naturamin WSP was associated with the significantly lowest share of deformed tubers in the yield and a greater reduction in all defects compared to other plots. A decreasing trend was found in our previous study for the share of tubers deformed and with greening in plants treated with amino acid biostimulants (Trawczyński 2014). Analysis of the effects of biostimulants in individual years revealed a decrease in the sum of tuber defects during the dry year and an increase during the very dry year compared to the control plot. Regardless of the biostimulants used, the number of tubers with greenings was significantly higher in the dry year, while in the very dry year there were significantly more tubers infected with common scab. The greater share of tubers with greenings could be attributed to the greater weight of tuber yield in 2018, and the greater share of tubers infected with common scab could be attributed to a very large shortage of rainfall during the tuberization period (June) in 2019. The analysis demonstrated that the weather conditions in the years had the strongest effect on tuber greening and infestation with common scab (92 and 98.9% share in total variance, respectively), while interaction between years and used biostimulants had the strongest effect on the share of deformed tubers and the sum of defects in the yield. A similar strong effect of weather conditions on the share of tubers with defective appearance, including deformed ones, was shown in the study by Lutomirska and Jankowska (2012).

The chemical analysis of tubers revealed significant differences in all components between plants treated with biostimulants and control plants (Table 5). On average, in the study years the content of starch in tubers was significantly higher in plants treated with Naturamin Plus and Krzemian

Tabela 4
Table 4

Wpływ dolistnego dokarmiania na udział w plonie bulw z wadami wyglądu (%)

The effect of foliar fertilization on share in yield of tubers with defects (%)

Obiekt Object	Zdeformowane Deformations	Zazielenione Greenings	Parch zwykły Common scab	Suma wad Sum of defects
Obiekt kontrolny*	9,1 ba	3,0 a	2,5 a	14,6 a
Krzemian	10,2 a	3,0 a	2,4 a	15,6 a
Naturamin Plus	9,1 ba	3,6 a	2,4 a	15,1 a
Naturamin WSP	8,5 b	3,5 a	2,4 a	14,4 a
2018	8,9 a	4,0 a	2,2 b	15,1 a
2019	9,6 a	2,5 b	2,7 a	14,8 a
Obiekt kontrolny*/2018	10,1 a	3,3 b	2,5 a	15,9 a
Krzemian/2018	9,2 ba	3,9 ba	2,2 ba	15,3 a
Naturamin Plus/2018	8,0 b	4,6 ba	2,0 b	14,6 a
Naturamin WSP/2018	8,1 b	4,3 a	2,0 b	14,4 a
Obiekt kontrolny */2019	8,2 b	2,7 a	2,5 a	13,4 b
Krzemian/2019	11,3 a	2,1 b	2,6 a	16,0 a
Naturamin Plus/2019	10,2 ba	2,7 a	2,8 a	15,7 a
Naturamin WSP/2019	8,9 ba	2,7 a	2,8 a	14,4 ba
Udział w wariancji całkowitej / Share in total variance (%)				
Preparat/Formula (1)	25	4,6	1,0	2,7
Lata/Years (2)	30	92,0	98,9	32,0
(1x2)	45	3,4	0,1	65,3

**Control object; Średnie z tymi samymi literami nie różnią się istotnie / Means with the same letter do not differ significantly.*

compared to the control plants. This is consistent with findings by Mystkowska (2019), who reported a significantly positive effect of various foliar biostimulants on the starch content in tubers. However, our previous study found no changes in the starch content in tubers after the use of amino acid biostimulants compared to the control plants (Trawczyński 2014). Differences in the content of starch in tubers from plants treated with biostimulants were similar to differences in the dry matter content (Table 5). Regardless of the year studied, all biostimulants contributed to a significant increase in the vitamin C content in tubers. The significantly highest content of vitamin C was found in tubers from plants treated with Naturamin WSP (Table 5). Treatment with Krzemian was associated with a significant decrease in the content of nitrates in tubers, both compared to the control plot and other biostimulants. Wróbel (2012) also reported a significant reduction in the content of nitrates (V) in tubers after treatment with Actisil containing silicon. Treatments with amino acid biostimulants were associated with a higher content of nitrates (V) in tubers compared to the control plants (Trawczyński 2014). Significant differences in the analysed components were also found between study years. The content of starch and dry matter was higher in tubers harvested in 2019, when the deficit of rainfall was greater and air temperature was lower than in 2018, while the opposite relationship was found for the content of nitrates and vitamin C in tubers. Studies by different researchers also showed that dry summers promoted the increase in vitamin C content in tubers (Gąsiorowska and Zarzecka 2002 Kraska 2002 Mazurczyk and Lis 2004). Dry years with higher air temperature also had a more positive effect on the accumulation of dry matter and starch in tubers than wet and cool years (Kołodziejczyk and Szmigiel 2012, Rymuza et al. 2015). However, the extremely high temperatures recorded during the growing season of 2018 had a significant negative impact on the accumulation of these compounds in tubers compared to 2019. On the other hand, shortage of rainfall and high air temperature may cause excessive accumulation of nitrates (V) in tubers, as reported by Grudzińska and Zgórska (2008). Our study showed that the dry growing season with extremely high air temperature had a particularly negative effect through a significant increase in the accumulation of nitrates (V). The

Tabela 5
Table 5

Wpływ dolistnego dokarmiania na skład chemiczny bulw ziemniaka

The effect of foliar fertilization on chemical composition of potato tubers

Obiekt Object	Skrobia Starch $g \cdot kg^{-1}$	Azotany (V) Nitrates (V) $mg \cdot kg^{-1}$	Witamina C Vitamin C $mg \cdot kg^{-1}$	Sucha masa Dry matter $g \cdot kg^{-1}$
Obiekt kontrolny*	122 c	94 b	227 d	188 c
Krzemian	132 a	82 c	236 b	198 a
Naturamin Plus	133 a	107 a	234 c	197 a
Naturamin WSP	126 b	108 a	240 a	191 b
2018	119 b	132 a	239 a	184 b
2019	138 a	63 b	230 b	203 a
Obiekt kontrolny */2018	119 a	108 b	231 d	184 a
Krzemian/2018	119 a	108 b	241 b	184 a
Naturamin Plus/2018	119 a	155 a	240 a	185 a
Naturamin WSP/2018	118 a	160 a	243 c	185 a
Obiekt kontrolny */2019	126 c	81 a	223 d	192 d
Krzemian/2019	146 a	56 b	231 b	213 a
Naturamin Plus/2019	146 a	59 b	229 c	209 b
Naturamin WSP/2019	134 b	57 b	238 a	198 c
Udział w wariancji całkowitej/ Share in total variance (%)				
Preparat/Formula (1)	6,0	2,9	29,3	6,3
Lata/Years (2)	88,2	91,0	69,3	87,8
(1x2)	5,8	6,1	1,4	5,9

**Control object; Średnie z tymi samymi literami nie różnią się istotnie / Means with the same letter do not differ significantly.*

analysis of variance components revealed that the study year accounted for 69.3% of total variability in vitamin C content to 91% of total variability in nitrates (V) content in tubers, while the use of biostimulants had the strongest effect on the content of vitamin C in tubers.

Conclusions

1. Treatments with the tested biostimulants were associated with a significant increase in the yield of tubers and positive effects on the content of nutrients in tubers compared to control plants.
2. Biostimulants had a more positive effect on tuber yield in the first year of the study, when the deficit of rainfall was lower and air temperature was higher than in the second year of the study.
3. Differences in weather conditions between the study years had a much greater impact on the yield of tubers and their quality parameters than treatments with biostimulants.

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