




IMPACT OF GROWTH BIOSTIMULATORS AND HERBICIDE ON THE YIELD STRUCTURE OF EDIBLE POTATO TUBERS (*SOLANUM TUBEROSUM* L.)

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Abstract. The aim of the research was to define the influence of treatment methods, with the use of growth biostimulators and herbicide on the yield structure of three varieties of edible potato. The series of field research was carried out in the years 2015-2017, in the region of eastern Poland, in Biała Podlaska municipality, in Lubelskie voivodship, on light, acidic soil. The experiment was constructed with the use of random sub-blocks method in three repetitions. The tested factors included: I. factor – three early edible potato varieties Owacja, Bellarosa, Vineta; II. factor – five methods of treatment of the field of potato crops with the use of growth biostimulators: GreenOk-Uniwersal Pro and Asahi SL and their combinations with Avatar 293 ZC herbicide. As a result of the conducted research it was found that the methods of treatment with the use of growth biostimulators and herbicide had a positive effect on the structure of potato tuber yields, compared to the standard object on which only mechanical care was applied. The highest weight percent of large tubers input (in fractions >51mm) was observed in case of experimental object 4. (in case of which herbicide Avatar 293 ZC and GreenOK Universal-PRO preparation were applied) as well as experimental object 3 (post applying biostimulator Asahi SL). Varieties cultivated in the experiment had a significant impact also on the structure of potato crops. An impact of weather conditions on the structure of potato tubers was further noted. Based on the conducted experiment, it can be concluded that the growth biostimulators, as well as their combination with herbicide, positively influenced the quality parameters of potato tubers. Therefore, these preparations should find wider application in agricultural practice.

Keywords: potato, harvest structure, GreenOK Universal-PRO, Asahi SL, Avatar 293 ZC

INTRODUCTION

Potato (*Solanum tuberosum* L.) is an important agricultural plant, not only on account of its consumable value but also its industrial and fodder values. It occupies a significant place in shifting cultivation (Zarzecka *et al.* 2017). Nowadays, the

production of potato continues to increase worldwide. The world production of this plant amounted to 376.8 million tonnes in 2016, while in 2017 this number increased to 388.2 million tonnes. Poland remains on the eighth place in the world and on the fourth place in Europe in terms of potato production (9.2 million tonnes). The world potato industry is undergoing substantial changes. Until the early 90s major part of potatoes was grown and consumed in Europe, North America and former Soviet Union. In the '90s of the last century the world faced an increase in the production and demand for potatoes among the developing countries of: Asia, Africa and Latin America. Currently, one-third of all potatoes are harvested in China and India (FAOSTAT 2019).

In Poland, despite a decreasing cultivation acreage, potato consumption is still high and it totals at about 100 kg/person/year. However, there is a tendency of constant decrease of fresh potatoes consumption, while the consumption of processed potatoes continues to increase (Potato Market 2015, Report of the Bank of Food Industry and Agriculture Bank 2015).

The basic parameter of quality of tubers in potato production is their appropriate size. The share in the harvest of tubers of various sizes is determined by the harvest structure. The size of potato tubers is one of many indicators of the usable value of varieties, depending on the direction of production. Edible tubers ought to have a diameter exceeding 35 mm, while tubers intended for chips – exceeding 55 mm, and for potato crisps between 40 and 70 mm (Regulation 2003, Chotkowski and Pilecki 2005, Zarzyńska 2012).

Plenty of factors have an influence on the potato crop size and its structure, among others, genetic traits of varieties, environmental and agronomic factors. (Krzysztofik *et al.* 2009, Essah *et al.* 2012, Radzka *et al.* 2015, Rymuza *et al.* 2015).

Currently, global trends in plant production are aimed at transforming intensive cultivation of crops into cultivation systems with a reduced share of synthetic fertilizers and chemical means of production for the protection of human and animal life and health as well as for environment protection purposes. New fertilizers and modern fertilization techniques will become increasingly applied in order to improve the quality of crops for the sake of environmental protection in the potato cultivation. On the other hand, chemical plant protection products will be increasingly used on the basis of monitoring threats related to pathogens (Jabłoński 2009, 2012). A very important element of the changes taking place in potato agro-technics is the commonly created process of the so-called “Green marketing of agricultural production space” (Nowacki 2005).

Due to the above, various types of ecological preparations, named biostimulators, are more and more often introduced into agricultural practice (Calvo *et al.* 2014). These preparations do not have a fertilizing effect, they mostly function on the basis of stimulating physiological processes in plants, increasing the effectiveness of using nutrients and increasing the resistance of plants to stressful

conditions (Kunicki *et al.* 2010, Bulgari *et al.* 2015, Matyaszczyk 2015). They may also positively influence some of the physicochemical features of soil and support the development of beneficial soil microorganisms (Vernieri *et al.* 2002). Their chemical composition includes many components with stimulating properties, such as: humus substances, effective microorganisms, phytohormones, enzymes, seaweed and fruit extracts, chitin, chitosan, poly-oligosaccharides, chemical elements, inorganic salts, phenolic compounds and many other substances with biologically active properties (Kauffman *et al.* 2007, Khan *et al.* 2009, Du Jardin 2012, 2015).

Scarce and ambiguous empirical findings about the influence of growth biostimulators on quality traits of potato tubers encourage further examinations. The aim of the experiment was to observe the impact of five methods of treatment using growth biostimulators and herbicide on the structure of potato tubers. The research hypothesis assumed that treatment methods with the use of growth biostimulators and herbicide would have a positive effect on the potato tuber yield structure through an increased share of large tubers in a yield.

MATERIALS AND METHODS

Experiment and plant material

The field research was carried out in the years 2015-2017, in the region of eastern Poland, in Biała Podlaska municipality (52°02'N 23°07'E), in Lubelskie voivodship, on light, acidic soil classified as quality class IVa. Soil was characterised by very high content of easy absorbed phosphorus and potassium forms. On the other hand, the amount of absorbed magnesium in soil was from average to very high.

The impact of two factors was tested in the experiment:

I. Factor – varieties of edible potato: Bellarosa, Owacja, Vineta;

II. Factor – five methods of treatment of potato field with the use of growth and herbicide biostimulators (Tab. 1).

Each year of carrying out the experiment, in autumn, fertilizing with natural manure was used at a dose of 25 t ha⁻¹ as well as mineral – phosphorous at a dose of 44.0 kg P ha⁻¹ (triple superphosphate 46%) and potassium 124.5 kg K ha⁻¹ (potassium salt 60%). In contrast, in spring, nitrogen fertilization (ammonium nitrate 34%) at a dose of 100 kg N per 1 ha was applied. Potato tubers were planted in the second decade of April (in 2015 and 2016) and in the third decade of April (in 2017). Treatments against diseases and pests were used in accordance with the plant protection recommendations and carried out on cloudy days in the afternoon hours. A battery sprayer equipped with a standard flat-jet nozzle (015-80, in accordance with the ISO standard) was applied to carry out chemical treatments. Potato plantation was protected with insecticides: Actara 25 WG (thiamethoxam 250 g kg⁻¹) at

a dose of 0.08 kg ha⁻¹, Calypso 480 SC (thiachloprid 480 g dm³) at a dose of 0.1 dm³ ha⁻¹ and fungicides: Copper Max New 50 WP (copper – 500 g kg⁻¹) at a dose of 2.0 kg ha⁻¹ Dithane Neo Tec 75 WG (mancozeb 750 g kg⁻¹) at a dose of 2.0 kg ha⁻¹.

Table 1. Methodical data of the experiment

Treatment methods	
1.	Standard object – mechanical treatment (without biostimulators and herbicide)
2.	From sprouting of potato plants – mechanical treatment and after sprouting – *GreenOK Universal–PRO bioactivator, three times to leaves: at a dose of 0.10 dm ³ ha ⁻¹ (phase BBCH 13-19) + 0.15 dm ³ ha ⁻¹ (phase BBCH 31-35) + 0.15 dm ³ ha ⁻¹ (phase BBCH 51-55).
3.	From sprouting of potato plants – mechanical treatment, and after sprouting – **Asahi SL bioactivator, three times to leaves at a dose of 0.50 dm ³ ha ⁻¹ (phase BBCH 13-19) + 0.50 dm ³ ha ⁻¹ (phase BBCH 31-35) + 0.50 dm ³ ha ⁻¹ (phase BBCH 51-55).
4.	From sprouting – mechanical treatment, and after the final shaping of ridges and just before sprouting ***Avatar 293 ZC herbicide at a dose of 1.5 dm ³ ha ⁻¹ (phase BBCH 00-05). After sprouting – three applications of GreenOK Universal–PRO bioactivator at a dose of 0.10 dm ³ ha ⁻¹ (phase BBCH 13-19) + 0.15 dm ³ ha ⁻¹ (phase BBCH 31-35) + 0.15 dm ³ ha ⁻¹ (phase BBCH 51-55).
5.	From sprouting – mechanical treatment, and after the final shaping of ridges before sprouting of potato plants – Avatar 293 ZC herbicide at a dose of 1.5 dm ³ ha ⁻¹ (phase BBCH 00-05).

*GreenOK Universal-PRO bioactivator (humus substances ≥ 20 g dm³, and NPK 0.13-0.09-0.7);

Asahi SL bioactivator (sodium para-nitrophenolate (0.3%), sodium orto-nitrophenolate (0.2%), sodium-nitroguaiacolate (0.1%); *Avatar 293 ZC herbicide (clomazone (5.13%), metribuzin (20.64%))

The harvest was performed in the phase of full technological ripeness of potato tubers. The area of harvest fields totalled 20 m². During the harvest, randomly chosen samples of 10 potato plants (with the exception of marginal plants) were collected from each experimental object. In these samples, the structure of harvest was determined according to the fractions with transverse diameter: up to 35, 36-50, 51-60 and above 60 mm. The total potato harvest was calculated on the basis of the mass of tubers collected from the surface of each plot of land, adding the mass of previously collected samples. The harvest of fractions with a diameter above 51 mm was classified to the harvest of large tubers. The results of research concerning total yield have been presented in the work of Baranowska (2018). The results of research on the impact of treatment methods on the harvest structure of potato tubers are based on average percentage values.

Statistical analysis

A study was carried out on the impact of care and cultivation methods, varieties and weather conditions on the structure of edible potato tuber yield. The obtained research results were elaborated statistically with the use of analysis of variations. The significance of changeability sources was researched by means of *F* Fisher-Snedecor test and the assessment of significance of differences at the significance level $p = 0.05$ between the averages compared using the multiple Tukey intervals.

Weather conditions

The precipitation and thermal conditions during the growing season of potato have been shown in Table 2. The data come from the Meteorological Station of the Polish Official Variety Testing Centre (COBORU) in Słupia Wielka and they were elaborated for the Experimental Station for the Evaluation of Varieties in Cicibór Duży, located near Biała Podlaska. Atmospheric conditions were characterized in the course of several consecutive years (1990-2010) on the basis of average monthly air temperatures (°C), monthly precipitation sums (mm), and Sielianinov's thermal coefficient (*K*). Extremely dry and extremely humid conditions were distinguished, dividing the values of the Sielianinov's (*K*) coefficient into nine classes according to Skowera (2014).

Table 2. Meteorological conditions in potato's growing season (mean for years 2015–2017)

Month / Year	Air temperature (°C) (monthly mean)	Air temperature (°C) (many years' mean 1990-2010)	Precipitation sum (mm)	Precipitation sum (mm) (many years' mean 1990-2010)	Sielianinov hydrothermal coefficient (K)	*Month's classification according to Skowera (2014)
2015						
IV	8.3	8.3	36	38	1.43	optimal
V	12.8	13.9	91	61	2.28	humid
VI	16.7	17.0	30	60	0.59	very dry
VII	19.6	19.4	49	77	0.80	dry
VIII	21.6	18.3	7	68	0.11	extremely dry
IX	15.1	12.7	75	57	1.66	quite humid
Mean / Sum	15.7	14.9	288	361	0.99	
2016						
IV	9.7	8.3	35	38	1.19	quite dry
V	15.0	13.9	22	61	0.47	very dry
VI	18.4	17.0	84	60	1.53	optimal
VII	19.8	19.4	121	77	1.97	quite humid
VIII	18.7	18.3	28	68	0.48	very dry
IX	15.2	12.7	12	57	0.26	extremely dry
Mean / Sum	16.1	14.9	302	361	1.0	
2017						
IV	7.7	8.3	62	38	2.68	very humid
V	13.8	13.9	40	61	0.93	dry
VI	18.0	17.0	106	60	1.97	quite humid
VII	18.5	19.4	71	77	1.24	quite dry
VIII	19.9	18.3	41	68	0.66	very dry
IX	14.7	12.7	105	57	2.37	extremely humid
Mean / Sum	15.4	14.9	425	361	1.50	

*Month's classification according to Skowera (2014): extremely dry $K \leq 0.4$, very dry $0.4 < K \leq 0.7$, dry $0.7 < K \leq 1.0$, quite dry $1.0 < K \leq 1.3$, optimal $1.3 < K \leq 1.6$, quite humid $1.6 < K \leq 2.0$, humid $2.0 < K \leq 2.5$, very humid $2.5 < K \leq 3.0$, extremely humid $K > 3.0$

Varied meteorological conditions were in place during the research (Tab. 2). In the growing season of 2015 there was a high precipitation deficit in the period from June to August, and the month of August was extremely dry with a total rainfall of 7 mm and high temperatures of atmospheric air. The Sielianinov's (K) hydrothermal coefficient this month was at the level of 0.11. In contrast, the most humid season compared to the remaining years of the study was the 2017 vegetation season in which the total rainfall amounted to 425 mm and it was higher than the average sum from the long-term period by 64 mm. The thermal and rainfall conditions were more favourable as compared to the remaining years of research in the growing season of 2016. The most humid months included: July with total rainfall of 121 mm and high air temperatures (average 19.8°C) and June with total precipitation of 84 mm and average air temperature of 18.4°C (Tab. 2).

RESULTS AND DISCUSSION

The impact of methods of treatment on the structure of potato tubers

When analysing the results of own research it was noted that the methods of treatment with the use of growth biostimulators and herbicide had a positive impact on the structure of potato tubers crop. Based on the conducted statistical calculations, it was noted that the weighted, percentage share of the tubers in the general crop in fractions below 35 and 36-50 mm (Tabs 3 and 4) was indeed higher in case of experimental object 1, on which only mechanical treatment was applied (without

Table 3. The impact of methods of treatment on the weighted and percentage share of potato tubers in fractions < 35 mm (on average for cultivars and years 2015-2017)

Methods*	Cultivars			Years			Mean
	Bellarosa	Owacja	Vineta	2015	2016	2017	
1*	8.60	8.13	14.08	11.29	8.07	11.45	10.27
2	6.15	5.45	8.97	9.37	4.21	6.99	6.86
3	4.00	5.04	6.50	6.17	4.50	4.87	5.18
4	2.01	4.00	5.10	4.18	3.47	3.47	3.71
5	3.01	6.04	7.33	5.52	5.31	5.55	5.46
Mean	4.75	5.73	8.40	7.31	5.11	6.47	6.30
LSD (0.05) for: Years							n.s.
							Cultivars
							1.060
							Methods
							1.116
							Years × methods
							n.s.
							Cultivars × methods
							n.s.

* – as in the research methodology: 1. Standard; 2. object (without biostimulators and herbicide); 3. GreenOK Universal-PRO 0.10 dm³ ha⁻¹ + 0.15 dm³ ha⁻¹ + 0.15 dm³ ha⁻¹; 4. Asahi SL 0.50 dm³ ha⁻¹ + 0.50 dm³ ha⁻¹ + 0.50 dm³ ha⁻¹; 5. Avatar 293 ZC 1.5 dm³ ha⁻¹ + GreenOK Universal-PRO 0.10 dm³ ha⁻¹ + 0.15 dm³ ha⁻¹ + 0.15 dm³ ha⁻¹; 6. Avatar 293 ZC 1.5 dm³ ha⁻¹; n. s. – not significant difference

growth biostimulators and herbicide) – for small tubers in fractions below 35 mm it was on average 10.27% and in fractions 36-50 mm – 33.6%. The smallest percentage of small tubers in general crop (in fractions: < 35 mm and 36-50 mm) was found in case of experimental object 4 (on average 3.71 and 14.74%) (Tabs 3 and 4), on which mechanical treatment methods were applied and shortly before emergences of potato plants, on the wet soil the plants were treated with a herbicide called Avatar 293 ZC at a dose of $1.5 \text{ dm}^3 \text{ ha}^{-1}$. Then, during the plants' growing period a humus bioactivator GreenOK Universal-PRO was applied three times at a combined dose of $0.40 \text{ dm}^3 \text{ ha}^{-1}$, as well as on experimental object 3 (on average 5.18 and 23.04%), on which mechanical treatment methods were used until the emergence of potato plants followed by the application of a biostimulator Asahi SL at a combined dose of $1.5 \text{ dm}^3 \text{ ha}^{-1}$ (Tabs 3 and 4).

Table 4. The impact of methods of treatment on the weighted and percentage share of edible potato tubers in fractions 36-50 mm (on average for cultivars and years 2015-2017)

Methods*	Cultivars			Years			Mean
	Bellarosa	Owacja	Vineta	2015	2016	2017	
1*	17.07	40.87	42.25	39.04	25.60	35.55	33.40
2	14.85	36.22	40.36	38.96	23.46	29.01	30.48
3	4.67	26.96	37.50	25.50	20.83	22.80	23.04
4	4.99	15.33	23.90	20.82	10.53	12.87	14.74
5	10.99	28.29	39.67	34.81	22.69	21.45	26.32
Mean	10.51	29.53	36.74	31.83	20.62	24.34	25.60
LSD (0.05) for:	Years						1.991
	Cultivars						1.991
	Methods						1.956
	Years × methods						n.s.
	Cultivar × methods						n.s.

* – as in the research methodology: 1. Standard; 2. object (without biostimulators and herbicide); 3. GreenOK Universal-PRO $0.10 \text{ dm}^3 \text{ ha}^{-1} + 0.15 \text{ dm}^3 \text{ ha}^{-1} + 0.15 \text{ dm}^3 \text{ ha}^{-1}$; 4. Asahi SL $0.50 \text{ dm}^3 \text{ ha}^{-1} + 0.50 \text{ dm}^3 \text{ ha}^{-1} + 0.50 \text{ dm}^3 \text{ ha}^{-1}$; 5. Avatar 293 ZC $1.5 \text{ dm}^3 \text{ ha}^{-1} + \text{GreenOK Universal-PRO } 0.10 \text{ dm}^3 \text{ ha}^{-1} + 0.15 \text{ dm}^3 \text{ ha}^{-1} + 0.15 \text{ dm}^3 \text{ ha}^{-1}$; 6. Avatar 293 ZC $1.5 \text{ dm}^3 \text{ ha}^{-1}$; n. s. – not significant difference

Whilst, in case of experimental objects 4 and 3 the largest weight and percentage share of large tubers (in fractions > 51 mm) was noted. It amounted to, on average: 81.56 and 71.78% (Tab. 5). Such authors as Sawicka and Pszczółkowski (2003), Zarzecka *et al* (2014) indicate a positive impact of herbicides and their mixtures on the structure of potato crops. Matysiak and Adamczewski (2010), Trawczyński (2014) proved that foliar fertilization of potato plants using biostimulators has caused a decrease of the share of small tubers in general crop (in fractions up to 35 mm) and an increase of the share of large tubers (in fractions: 50-60 mm and over 60 mm). Kowalska (2016) noted a beneficial effect of microbiological substances on potato crop and its structure regardless of the substance used and the form of its application.

Furthermore, Maciejewski *et al.* (2007) in their 2-year research concluded that using biostimulators Asahi SL and Atonik SL did not have any significant impact on the structure of potato tubers. Condor *et al.* (2006) shared a sceptical view on the topic of using microbiological preparations in plant production, stressing the need to conduct further scientific researches concerning their use.

Table 5. The impact of methods of treatment on the weight and percentage share of potato tubers in fractions >51 mm (on average for cultivars and years 2015-2017)

Methods*	Cultivars			Years			Mean
	Bellarosa	Owacja	Vineta	2015	2016	2017	
1*	74.33	51.00	43.67	49.67	66.33	53.00	56.33
2	79.00	58.33	50.67	51.67	72.33	64.00	62.67
3	91.33	68.00	56.00	68.33	74.67	72.33	71.78
4	93.00	80.67	71.00	75.00	86.00	83.67	81.56
5	86.00	65.67	53.00	59.67	72.00	73.00	68.22
Mean	84.73	64.73	54.87	60.87	74.27	69.20	68.11
LSD (0.05) for: Years							2.626
Cultivars							2.626
Methods							2.324
Years × methods							n.s.
Cultivars × methods							n.s.

* – as in the research methodology: 1. Standard object (without biostimulators and herbicide); 2. GreenOK Universal-PRO 0.10 dm³ ha⁻¹ + 0.15 dm³ ha⁻¹ + 0.15 dm³ ha⁻¹; 3. Asahi SL 0.50 dm³ ha⁻¹ + 0.50 dm³ ha⁻¹ + 0.50 dm³ ha⁻¹; 4. Avatar 293 ZC 1.5 dm³ ha⁻¹ + GreenOK Universal-PRO 0.10 dm³ ha⁻¹ + 0.15 dm³ ha⁻¹ + 0.15 dm³ ha⁻¹; 5. Avatar 293 ZC 1.5 dm³ ha⁻¹; n. s. – not significant difference

The impact of genetic properties of different cultivars on the structure of potato tubers

In the framework of own researches specific fractions of tubers were substantially modified by genetic features of the cultivated varieties of potato. When analysing the impact of varieties on the weight and percentage share of the fraction, it was concluded that Bellarosa variety had a decidedly larger share of tubers with a diameter of more than 51 mm (on average 84.73%) than Owacja variety (on average 64.77%) and Vineta (on average 54.87%) (Tab. 5). Bellarosa variety also had the smallest percentage of small tubers (in fractions < 35 mm and 36-50 mm) in general crop (Tabs 3 and 4). Turska *et al.* (2009) have also proven that the structure of potato crop is modified by the genetic characteristics of different varieties of potatoes. The authors emphasized that the use of yield possibilities of a given variety can be decided through the correct agricultural technology. Sawicka and Pszczółkowski (2017) have proved in their research that the interaction between genotype and environment have modified the structure of potato tubers to the largest extent.

The impact of thermal-precipitation conditions on the structure of potato tubers

The structure of potato tubers has been shaped by weather conditions in the years of research. The most beneficial for the shaping of the structure of potato tubers in fractions over 51 mm was the growing season of 2016, in which the thermal-precipitation conditions were more favourable in comparison to the other years of research. Whilst, the biggest share of small tubers in the potato crop occurred in the post-drought and warm growing season in 2015 (Tabs 3 and 4). These results comply with the research carried out by Gugala *et al.* (2010), who concluded that the largest volume of small tubers (in fractions < 35 mm) grew from potato plants in a warm and dry growing season, while the least appeared when the thermal-precipitation conditions were the most favourable. Lahlou *et al.* (2003) indicated that drought has a negative effect on the quality parameters of potato tubers. Kalbarczyk (1999), based on several years of research, noted that potato harvest can be affected negatively by insufficient, as well as excessive humidity of the soil. Zarzyńska (2010) in her research emphasized that a crucial element in potato cultivation is the right choice of potato variety, taking into consideration their environmental requirements.

CONCLUSIONS

1. The structure of edible potato tubers has been substantially influenced by the methods of treatment. Growth biostimulators and herbicides that were used in the experiment had a positive effect on the weight and percentage share of large tubers in general crop (in fractions >51 mm) as contrasted with the control experimental object that was treated solely in a mechanical way, in case of which a greater share of small tubers was observed.

2. The most effective manner of potato treatment in terms of the crop structure was using mechanical treatments until the emergence of plants and, right before the emergence, applying herbicide Avatar 293 ZC, and after the emergence, using bioactivator GreenOK Universal-PRO (experimental object 4), and until the emergence performing mechanical treatments, and after the emergence applying biostimulator Asahi SL (experimental object 3).

3. Genetic characteristics of the different varieties had an important impact on the structure of the crop – the greatest percentage share of large tubers in fractions over 51 mm was found in the Bellarosa cultivar; this variety had also the smallest share of small tubers.

4. Weather conditions were noted to have an impact on the structure of potato tubers. The most beneficial, as compared with the other years of research, for the shaping of the structure of crop in fractions over 51 mm was the growing season of 2016, whereby total precipitation in the growing season amounted to 302 mm and the average ambient temperature equalled 14.9°C.

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