doi: 10.17221/21/2018-PSE

The effect of herbicides and biostimulants on sugars content in potato tubers

Krystyna ZARZECKA*, Marek GUGAŁA

Department of Agrotechnology, Siedlce University of Natural Sciences and Humanities, Siedlce, Poland

**Corresponding author: kzarzecka@uph.edu.pl*

ABSTRACT

Zarzecka K., Gugała M. (2018): The effect of herbicides and biostimulants on sugars content in potato tubers. Plant Soil Environ., 64: 82–87.

The objective of the present work was to determine changes in total sugars, reducing sugars and sucrose content in potato tubers under conditions involving an application of biostimulants and herbicides. Research material included table potato tubers obtained in a three-year field experiment. The experiment was a split-plot design with three replicates. The factors were as follows: factor I – three table potato cultivars (Bartek, Gawin and Honorata), factor II – five methods of biostimulant and herbicide application (1. control – without biostimulants or herbicides; 2. Harrier 295 ZC (linuron + chlomazon); 3. Harrier 295 ZC (linuron + chlomazon) and growth regulator Kelpak®SL; 4. Sencor 70 WG (metribuzin); 5. Sencor 70 WG (metribuzin) and growth regulator Asahi®SL. Variance analysis demonstrated that total sugars, reducing sugars and sucrose content were affected by the biostimulants and herbicides applied as well as cultivars and weather conditions. Compared with control, a significant increase in total sugars followed an application of Sencor 70 WG as well as Sencor 70 WG and the growth regulator Asahi®SL whereas reducing sugars and sucrose content significantly increased after Sencor 70 WG and the growth regulator Asahi®SL were applied.

Keywords: *Solanum tuberosum*; carbohydrate; pesticide

In modern agriculture, various products are applied in addition to herbicides, fungicides and insecticides to stimulate life processes, which increase resistance of plants to stress factors. Such products include biostimulants, growth regulators and products that contain microelements. Research has demonstrated that biostimulants positively affect both plant yields and qualitative attributes (Maciejewski et al. 2007, Wierzbowska et al. 2015), increase plant tolerance to environmental stressors (Calvo et al. 2014, Przybysz et al. 2016), and reduce an occurrence of diseases (Cwalina-Ambroziak et al. 2015).

Potato is one of the most important crop plants cultivated in Poland. Its basic use includes direct consumption, food processing and industrial processing (Leszczyński 2012). *Solanum tuberosum* yield levels and quality are affected by genetic factors, agrotechnological practices (including fertilization) as well as climatic and soil conditions (Hamouz et al. 2005, Hlušek et al. 2005, Wierzbowska et al. 2015, Leonel et al. 2015, Zarzyńska and Pietraszko 2015). The chemical composition of potato tubers for direct consumption and food processing should meet certain requirements, dry matter content, starch content, total sugars, reducing sugars and amino acids being particularly important (Haase et al. 2007, Lisińska et al. 2009). There are no reports in the available literature on practices combining an application of herbicides and biostimulants in potato cultivation. Thus, the aim of the study reported here was to assess the effect of an application of herbicides and biostimulants on sugar content in potato tubers.

Supported by the Ministry of Science and Higher Education of Poland, Project No. 214/04/S.

doi: 10.17221/21/2018-PSE

Table 1. Selected chemical properties of sand soil

Year	pH (1 mol KCl/L)	Organic carbon (g/kg)	Available nutrient (mg/kg soil)		
			P	K	Mg
2012	5.60 – slightly acidic	8.7	68.6 (high)	149.4 (very high)	50.0 (high)
2013	5.60 – slightly acidic	9.3	73.4 (high)	129.0 (high)	51.0 (high)
2014	6.35 – neutral	10.8	110.0 (very high)	149.4 (medium)	56.0 (high)

MATERIAL AND METHODS

A field experiment was conducted over three years in Wojnów (52°12'59''N, 22°34'37''E) on the soil belonging to quality class IVb, which represents rye very good class of agricultural suitability. Selected chemical soil properties prior to the experiment set-up are presented in Table 1. The experiment was designed as a split-plot arrangement in three replicates and it included two factors: factor I included three table potato cultivars, factor II included five methods of an application of herbicides and biostimulants (Tables 2 and 3).

The biostimulants Asahi SL and Kelpak SL were selected based on the list of plant conditioners, which can be traded on the Polish market compiled by the Ministry of Agriculture and Rural Development of 10 July 2007 (2007). In autumn, farmyard manure was used in the quantity of 25 t/ha as well as 44 kg P/ha (triple superphosphate) and 125 kg K/ha (potassium salt) and in the spring 100 kg N/ha (ammonium saltpeter). The potato tubers were planted by hand at 0.675 × 0.37 m spacing at the end of April, and were harvested at the beginning of September.

Before harvest, tuber samples from 10 plants per plot were collected in all experimental units and used for chemical analyses. Total sugars and reducing sugars were determined after harvest in the fresh matter of unpeeled potato tubers by means of the Schoorl-Luff method (Krełowska-Kułas 1993). The method involves reduction, under alkaline conditions, of copper sulphate by reducing sugars contained in Luff solution at the boiling temperature. Sucrose content was calculated by subtracting reducing sugars from total sugars after hydrolysis × 0.95. Analyses were performed at the Chemical Laboratory of the Department of Agrotechnology, Siedlce University of Natural Sciences and Humanities. The results of the experiments were analysed by ANOVA. Significance of sources of variation was checked with the Fisher-Snedecor test and mean values were separated with the Tukey's test at the significance level of 0.05.

The weather conditions varied over the growing seasons of potato cultivation (Table 4). The rainfall sum in the year 2012 was by 10.6 mm lower than the long-term mean whereas the average temperature over the potato growing season was by 0.7°C higher than the long-term mean. The Sielianinov's hydrothermal coefficient (K = 0.95) indicates that the year 2012 was slightly dry (K = 0.95). Rainfall was the highest in 2013, and the Sielianinov's hydrothermal coefficient was K = 1.6 – it was a wet season. Rainfall in 2014 was higher than the long-term precipitation sum and was irregularly distributed. Temperatures were higher by 0.6°C than the long-term mean and values of hydrothermal coefficient ranged between 0.16 and 2.30.

RESULTS AND DISCUSSION

Total sugars (glucose + fructose + sucrose) are important characteristics which determine culti-

Table 2. Description of potato cultivars (Nowacki 2015)

Cultivar	Registration year	Maturity	Yield (t/ha)	Starch (g/kg)	Processing
Bartek	2003	medium early	54.4	161	canned, frozen food, salads
Gawin	2010	medium early	44.7	164	chips
Honorata	2012	medium early	44.1	154	chips

doi: 10.17221/21/2018-PSE

Table 3. Factors of the experiment

Factor I	Three potato cultivars: Bartek, Gawin, Honorata
Factor II	Five methods of herbicides and biostimulants application (treatments)
	1. Control – mechanical weeding – without herbicides or biostimulants
	2. Harrier 295 ZC (linuron + chlomazon) at a dose of 2.0 L/ha
	3. Harrier 295 ZC (linuron + chlomazon) at a dose of 2.0 L/ha and growth regulators Kelpak®SL* at a dose of 2.0 L/ha
	4. Sencor 70 WG (metribuzin) at a dose of 1.0 kg/ha
	5. Sencor 70 WG (metribuzin) at a dose of 1.0 kg/ha and growth regulators Asahi®SL** at a dose of 1.0 L/ha

*Kelpak®SL (alga extract from *Ecklonia maxima* – 11 mg/L auxins and 0.031 mg/L cytokinins, the auxin to cytokinin ratio is 350:1); **Asahi®SL (contains phenols naturally occurring in plants: sodium para-nitrophenol, sodium ortho-nitrophenol, sodium 5-nitroguaiacol)

var suitability for direct consumption as well as processing for frozen foods, salads, pasteurised products (tinned food), chips and crisps, as tubers containing more than 1% of these compounds have got sweet flavour (Zgórska and Frydecka-Mazurczyk 2002, Grudzińska et al. 2016). The study reported here demonstrated that total sugars in the tubers of potato cultivars analysed ranged from 6.71 to 7.43 g/kg fresh matter (so it was less than 1%), and were significantly affected by cultivar, herbicides and biostimulants applied as well as weather conditions during the growing season (Table 5). Cv. Gawin accumulated the most total sugars, followed by cv. Honorata and Bartek, the latter containing significantly less total sugars. Statistically confirmed between-cultivar differences in the content of the component discussed were also reported by Bhattacharjee et al. (2014) and Zarzecka et al. (2017), whereas Sawicka and Pszczółkowski (2005) found no differences between cultivars as far as total and reducing sugars were concerned. The herbicide Harrier 295 ZC applied alone and in combination with the biostimulant Kelpak®SL (treatments 2 and 3) did not affect the concentration of total sugars whereas the herbicide Sencor 70 WG applied either alone or in combination with the biostimulant Asahi®SL (treatments 4 and 5) significantly increased total sugars. Sawicka

Table 4. Meteorologic conditions according to the Zawady Meteorological Station, Poland

Study year	Deviations from the long-term (1987–2000) mean						
	IV	V	VI	VII	VIII	IX	IV–IX
Rainfall (mm)							
2012	–8.7	+9.0	+23.8	–6.8	+8.0	–35.9	–10.6
2013	–2.6	+61.8	+46.4	+41.5	–28.0	+47.0	+166.1
2014	+6.4	+48.6	+3.0	–39.8	+62.7	–21.0	+59.9
Air temperature (°C)							
2012	+1.1	+2.1	–0.9	+1.5	–0.5	+1.0	+0.7
2013	–0.4	+2.8	+0.8	–0.2	+0.3	–1.4	+0.3
2014	+2.0	+1.0	–1.8	+1.6	–0.4	+1.0	+0.6
Sielianinov's hydrothermal coefficients							
2012	1.10	1.20	1.60	0.69	0.94	0.27	0.95
2013	1.60	2.30	1.80	1.60	0.30	2.70	1.60
2014	1.50	2.30	1.20	0.16	1.90	0.62	1.20

Coefficient values (Bac et al. 1998): up to 0.5 strong drought; 0.51–0.69 drought; 0.70–0.99 mild drought; ≥1 no drought

doi: 10.17221/21/2018-PSE

Table 5. Total sugars in potato tubers (g/kg fresh matter)

Treatment	Cultivar			Year			Mean
	Bartek	Gawin	Honorata	2012	2013	2014	
1	6.71	7.11	7.03	6.78	6.89	7.20	6.96
2	6.85	7.15	7.12	6.88	6.99	7.24	7.04
3	7.00	7.26	7.12	7.02	7.01	7.35	7.13
4	7.07	7.29	7.19	7.09	7.08	7.38	7.18
5	7.12	7.35	7.23	7.15	7.11	7.43	7.23
Mean	6.95	7.23	7.14	6.98	7.02	7.32	7.11

$LSD_{0.05}$ – for: cultivars: 0.10; treatments: 0.18; years: 0.10; interaction: treatments × years: 0.21

LSD – least significant difference

and Pszczółkowski (2005) and Gugała et al. (2013) found that herbicides had no effect on total sugars whereas Zarzecka et al. (2017) demonstrated that Plateen 41.5 WG and Racer 250 EC contributed to an increase in total sugars.

Based on the long-term studies, the optimum levels of reducing sugars as well as minimum and maximum values (glucose + fructose) in potato tubers were established. Potatoes destined for processing into crisps should contain up to 0.25% reducing sugars, the optimum value being up to 0.15%, whereas the maximum value for tubers for processing into chips should be 0.50%, the optimum value being less than 0.30%. As far as tubers for direct consumption and processing into frozen and tinned food are concerned, the maximum content of reducing sugars is 0.50% and the optimum value should not exceed 0.25% (Zgórska and Frydecka-Mazurczyk 2002, Lisińska et al. 2009). A higher amount of reducing sugars has an adverse effect on tuber colour, flavour and smell, and, in the case of fried products e.g. chips, acrylamide content, the component being harmful for human health (Lisińska et al. 2009, Grudzińska et al. 2016).

In the study reported here, cv. Honorata accumulated the least reducing sugars, followed by cv. Gawin that accumulated more, and cv. Bartek accumulating significantly the most reducing sugars (Table 6). The cultivars examined met the requirements set for potato for direct consumption. Moreover, Honorata and Gavin complied with the standards set for potato for processing into chips. The effect of cultivar-related characteristics on the accumulation of reducing sugars was reported by many authors (Maciejewski et al. 2007, Murniece et al. 2010, Bhattacharjeeet al. 2014, Zarzecka et al. 2017). An application of herbicides and bi-

Table 6. Reducing sugars in potato tubers (g/kg fresh matter)

Treatment	Cultivar			Year			Mean
	Bartek	Gawin	Honorata	2012	2013	2014	
1	3.02	2.77	2.74	2.76	2.97	2.81	2.85
2	3.05	2.80	2.79	2.83	2.99	2.83	2.88
3	3.07	2.82	2.80	2.84	2.99	2.86	2.90
4	3.05	2.84	2.81	2.81	2.98	2.91	2.90
5	3.07	2.85	2.84	2.84	2.98	2.95	2.92
Mean	3.05	2.82	2.80	2.81	2.98	2.87	2.89

$LSD_{0.05}$ – for: cultivars: 0.05; treatments: 0.06; years: 0.05; interaction: cultivars × treatments: 0.14; cultivars × years: 0.08

LSD – least significant difference

doi: 10.17221/21/2018-PSE

Table 7. Sucrose content in potato tubers (g/kg fresh matter)

Treatment	Cultivar			Year			Mean
	Bartek	Gawin	Honorata	2012	2013	2014	
1	3.58	4.13	4.04	3.81	3.80	4.14	3.92
2	3.60	4.13	4.11	3.83	3.81	4.20	3.95
3	3.74	4.21	4.10	3.98	3.82	4.26	4.07
4	3.84	4.22	4.16	4.07	3.91	4.24	4.07
5	3.84	4.25	4.17	4.10	3.93	4.24	4.09
Mean	3.72	4.19	4.12	3.96	3.85	4.22	4.01

$LSD_{0.05}$ – for: cultivars: 0.08; treatments: 0.16; years: 0.08; interaction: cultivars × treatments: 0.18

LSD – least significant difference

ostimulants slightly increased sugar concentration, a significant increase being noted in treatment 5 (Sencor 70 WG and the growth regulator Asahi SL) compared with control. Statistical analysis revealed an interaction between cultivars and treatments, which confirmed a different response to products applied in the study. Also Maciejewski et al. (2007) found that the biostimulants Asahi®SL and Atonik®SL contributed to a tendency for cv. Satina to increase reducing sugars, and for cv. Ditta to reduce the sugars.

Sucrose (disaccharide) content ranged from 3.58 to 4.26 g/kg fresh matter and was affected by the experimental factors (Table 7). The lowest sucrose content was determined in the tubers of cv. Bartek. It was significantly higher in cv. Honorata and Gawin (4.12 and 4.19 g/kg fresh matter, respectively). Research by Bhattacharjee et al. (2014) and Grudzińska et al. (2016) also demonstrated that sucrose content in potato tubers was cultivar-related. Herbicides and biostimulants increased sucrose content compared with the control tubers. Sawicka and Pszczółkowski (2005) as well as Gugała et al. (2013) observed only a tendency for sucrose content to increase due to an application of herbicides. The available literature lacks studies on the effect of biostimulants on sucrose content in potato tubers.

In their studies, Boguszewska (2007), Hamouz et al. (2007), Zarzecka and Gugała (2009) found that sugar concentration in potato tubers was barely stable and fluctuated markedly in individual study years. Statistical calculations demonstrated that weather conditions in the study years significantly affected the concentration of total sugars, reducing sugars and sucrose in *Solanum tuberosum* tubers (Tables 5–7). The highest concentrations of total sugars and sucrose were determined in tubers harvested in 2014 when precipitation during the growing season was irregularly distributed. By contrast, the least reducing sugars were accumulated in the wet and coldest season, compared with the long-term value. Varied sugar accumulation under changeable weather conditions is confirmed by the following interactions: cultivars × years (for reducing sugars and sucrose) and treatments × years (for total sugars). Similar changes were noted by Gugała et al. (2013). Also Boguszewska (2007) pointed to the fact that in all the cultivars she studied, total sugars and sucrose content increased due to the effect of a stressor.

REFERENCES

Bac S., Koźmiński C., Rojek M. (1998): Agrometeorology. Warszawa, Państwowe Wydawnictwo Naukowe, 274. (In Polish)

Bhattacharjee A., Roy T.S., Haque Md.N., Pulok Md.A.I., Rahman Md.M. (2014): Changes of sugar and starch levels in ambient stored potato derived from TPS. International Journal of Scientific and Research Publications, 4: 1–5.

Boguszewska D. (2007): Changes of chemical compounds in potato tubers under drought conditions. Żywność Nauka Technologia Jakość, 54: 93–101. (In Polish)

Calvo P., Nelson L., Kloepper J.W. (2014): Agricultural uses of plant biostimulants. Plant and Soil, 383: 3–41.

Cwalina-Ambroziak B., Głosek-Sobieraj M., Kowalska E. (2015): The effect of plant growth regulators on the incidence and severity of potato diseases. Polish Journal of Natural Sciences, 30: 5–20.

doi: 10.17221/21/2018-PSE

Grudzińska M., Czerko Z., Wierzbicka A., Borowska-Komenda M. (2016): Changes in the content of reducing sugars and sucrose in tubers of 11 potato cultivars during long term storage at 5 and 8°C. Acta Agrophysica, 23: 31–38. (In Polish)

Gugała M., Zarzecka K., Sikorska A., Dołęga H. (2013): Changes in sugar content in cultivars potato tubers depending on the weed control methods. Progress in Plant Protection, 53: 271–275. (In Polish)

Hamouz K., Čepl J., Dvořák P. (2005): Influence of environmental conditions on the quality of potato tubers. Horticultural Science, 32: 89–95.

Hamouz K., Dvořák P., Pazdera J. (2007): Influence of different soil-climatic conditions on the quality of table potatoes. Scientia Agriculturae Bohemica, 38: 6–12.

Haase T., Schüler C., Haase N.U., Hess J. (2007): Suitability of organic potatoes for industrial processing: Effect of agronomical measures on selected quality parameters at harvest and after storage. Potato Research, 50: 115–141.

Hlušek J., Jůzl M., Čepl J., Lošák T. (2005): The effect of selenium supplementation on its concentration in potato tubers. Chemické Listy, 99: 515–517.

Krełowska-Kułas M. (1993): Test the Quality of Food Products. Warszawa, Państwowe Wydawnictwo Ekonomiczne, 53–55. (In Polish)

Leonel M., do Carmo E.L., Fernandes A.M., Soratto R.P., Franco C.M.L., Ebúrneo J.A.M., Garcia É.L., dos Santos T.P.R. (2015): Chemical composition of potato tubers: The effect of cultivars and growth conditions. Journal of Food Science and Technology, 54: 2372–2378.

Leszczyński W. (2012): Nutrition value of potato and potato product (Review of literature). Biuletyn Instytutu Hodowli i Aklimatyzacji Roślin, 266: 5–20. (In Polish)

Lisińska G., Pęksa A., Kita A., Rytel E., Tajner-Czopek A. (2009): The quality of potato for processing and consumption. Food 3 (Special Issue 2): 99–104.

Maciejewski T., Szukała J., Jarosz A. (2007): Influence of biostimulant Asahi SL and Atonik SL on qualitative tubers of potatoes. Journal of Research and Applications in Agricultural Engineering, 52: 109–112. (In Polish)

Murniece I., Karklina D., Galoburda R., Sabovics M. (2010): Reducing sugar and colour intensity of fried Latvian potato varieties. Latvijas Lauksaimniecibas Universitate Raksti, 24: 20–30.

Nowacki W. (2015): Characteristics of the National Register of Cultivars of Potato. Jadwisin, XV Edition. Plant Breeding and Acclimatization Institute – National Research Institute, 1–43. (In Polish)

Przybysz A., Gawrońska H., Kowalkowski Ł., Szalachta E., Gawroński S.W. (2016): The biostimulant Asahi SL protect the growth of *Arabidopsis thaliana* L. plants when cadmium is present. Acta Scientiarum Polonorum – Hortorum Cultus, 15: 37–48.

Sawicka B., Pszczółkowski P. (2005): Dry matter and carbohydrates content in the tubers of very early potato varieties cultivated under coverage. Acta Scientiarum Polonorum, Hortorum Cultus, 4: 111–122.

Wierzbowska J., Cwalina-Ambroziak B., Głosek-Sobieraj M., Sienkiewicz S. (2015): Effect of biostimulants on yield and selected chemical properties of potato tubers. Journal of Elementology, 20: 757–768.

Zarzecka K., Gugała M. (2009): Changes in the content of total sugars present in potato tubers depending on the agrotechnical treatment. Roczniki Państwowego Zakładu Higieny, 60: 337–340. (In Polish)

Zarzecka K., Gugała M., Mystkowska I., Baranowska A., Sikorska A. (2017): Effect of herbicides on the content of dry matter and sugars in edible potato tubers. Romanian Agricultural Research, 34: 371–375.

Zarzyńska K., Pietraszko M. (2015): Influence of climatic conditions on development and yield of potato plants growing under organic and conventional systems in Poland. American Journal of Potato Research, 92: 511–517.

Zgórska K., Frydecka-Mazurczyk A. (2002): Standards and quality requirements of edible potatoes and for food processing. In: Chotkowski J. (ed.): Production and Marketing of Edible Potatoes. Warszawa, Wydawnictwo Wieś Jutra, 183–192. (In Polish)

Received on January 8, 2018
Accepted on January 19, 2018
Published online on January 31, 2018