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Changes in dry weight and starch content in potato under the effect of herbicides and biostimulants

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Abstract: The aim of the study was to determine the interaction of herbicides and herbicides with biostimulants on the accumulation of dry matter and starch in potato tubers. In a three-year field experiment based on the method of randomised sub-blocks, two factors were taken into account. The first factor were potato cultivars: Bartek, Gawin, Honorata. The second factor were five methods of herbicides and biostimulants application: (1) the control object without chemical protection (CO); (2) herbicide linuron + clomazone (Harrier 295 ZC) (H); (3) herbicide linuron + clomazone (Harrier 295 ZC) and biostimulant *Ecklonia maxima* (Kelpak SL) – (H + K); (4) herbicide metribuzin (Sencor 70 WG) – (S); (5) herbicide metribuzin (Sencor 70 WG) and biostimulant sodium para-nitrophenol, sodium ortho-nitrophenol, sodium 5-nitroguaiacol (Asahi SL) – (S + A). The cultivars and weather conditions significantly affected the content and yields of dry matter and starch. The herbicides and biostimulants used determined the starch accumulation as well as dry matter and starch yields. Most starch in tubers (more by 3.7 g/kg) and the highest dry matter and starch yields (more by 2.87 and 1.79 t/ha, respectively), compared to the control object, were obtained after the application of the herbicide Sencor 70 WG and biostimulant Asahi SL.

Keywords: *Solanum tuberosum* L.; tuberous crop; climatic conditions; rainfall

The content of dry matter and starch in potatoes are among the most important technological features determining the suitability of tubers for direct consumption, for food and non-food processing. Starch is the main ingredient in potato tubers and is closely correlated with the amount of dry matter (Grudzińska et al. 2015). The starch and dry matter content of edible potato cultivars registered in Poland is 11.0–20.4% and 17.1–27.3%, respectively (Nowacki 2017). The concentration of these components is determined by cultivar factors (Mareček et al. 2013, Grudzińska et al. 2015, Leonel et al. 2017), agrotechnical factors (Macák et al. 2012, Manolov et al. 2016) and weather (Zarzecka et al. 2017, Escuredo et al. 2018, Trawczyński 2018). Some researchers see the possibility of increasing the yield and improving the chemical composition of tubers under the conditions of using biostimulants or the combined use of herbicides with biostimulants (Pavlista 2011, Trawczyński 2018, Mystkowska 2019). Biostimulants are preparations that support the life processes of plants in a natural and safe way (Van Oosten et al. 2017). The research was aimed at determining whether treatments using herbicides and herbicides with biostimulants will have a positive effect on the accumulation of dry matter and starch in potato tubers and the yield of these ingredients.

MATERIAL AND METHODS

The research material were edible potato tubers from the field experiment carried out in 2012–2014.

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Table 1. Characteristics of the experiment

Parameter	2012	2013	2014
Geographical situation	52°12'59''N, 22°34'37''E	52°12'59''N, 22°34'37''E	52°12'59''N, 22°34'37''E
Texture class	sand	sandy loam	sandy loam
Soil acidity	slightly acidic	slightly acidic	neutral
Application of linuron + chlomazon (Harrier 295 ZC)	10. 05. 2012	18. 05. 2013	02. 05. 2014
Application of *Ecklonia maxima* (Kelpak SL)	06. 06. and 20. 06. 2012	12. 06. and 24. 06. 2013	31. 05. and 20. 06. 2014
Application of metribuzin (Sencor 70 WG)	22. 05. 2012	29. 05. 2013	18. 05. 2014
Application of sodium para-nitrophenol, sodium ortho-nitrophenol, sodium 5-nitroguaiacol (Asahi SL)	06. 06. and 20. 06. 2012	12. 06. and 24. 06. 2013	31. 05. and 20. 06. 2014
Date of planting	30. 04. 2012	08. 05. 2013	23. 04. 2014
Date of harvest	04. 09. 2012	04. 09. 2013	02. 09. 2014

The experiment was based on the method of randomised sub-blocks in a split-plot system, in three repetitions. Two factors were examined in the experiment: the first order factor were three medium early cultivars of edible potato: Bartek, Gawin, Honorata, and the second order factor were five methods of herbicides and biostimulants application, which included:
– control object without chemical protection – (CO);
– linuron + clomazone (Harrier 295 ZC) at a dose of 2.0 L/ha – (H);
– linuron + clomazone (Harrier 295 ZC) at a dose of 2.0 L/ha and *Ecklonia maxima* (Kelpak SL) at a dose of 2.0 L/ha – (H + K);
– metribuzin (Sencor 70 WG) – 1 kg/ha – (S);
– metribuzin (Sencor 70 WG) – 1 kg/ha and sodium para-nitrophenol, sodium ortho-nitrophenol, sodium 5-nitroguaiacol (Asahi SL) – 1.0 L/ha – (S + A).

The dates of application of herbicides and herbicides with biostimulants are presented in Table 1. The work of Gugała et al. (2018) presents a detailed description of the treatment used on objects with herbicides and biostimulants. Every autumn, permanent manure fertilisation was applied in the amount of 25.0 t/ha and mineral fertilisation of 44 kg P/ha and 125 kg K/ha, and in spring 100.0 kg N/ha. Each experimental plot for harvest was 2.75 m by 5.55 m with a plant spacing of 37 cm and row spacing of 67.5 cm. During harvest, samples of tubers from 10 potato plants per plot were collected, in which the starch content and tuber dry matter were determined. The starch content was determined hydrostatically on an electronic scale Reimann WPT 3CA (Radom, Poland). The tuber dry mass was determined by two-stage gravimetric drying, according to the Polish standard (Polish Norm PN-EN 12145, 2001). Samples of potato tubers were

Table 2. Average monthly air temperature and monthly total precipitation during the vegetative growth periods (Zawady Meteorological Station in Poland)

Month	Air temperature (° C)				Precipitation (mm)			
	2012	2013	2014	mean of 1980–2009	2012	2013	2014	mean of 1980–2009
April	8.9	7.4	9.8	7.9	29.9	36.0	45.0	49.6
May	14.6	15.3	13.5	11.2	53.4	105.9	92.7	48.2
June	16.3	18.0	15.4	16.7	76.2	98.8	55.4	60.7
July	20.7	19.0	20.8	19.3	43.0	91.3	10.0	45.7
August	18.0	18.8	18.1	18.0	51.0	15.0	105.7	53.0
September	14.1	11.7	14.1	13.0	11.4	94.3	26.3	50.7
Mean	15.4	15.0	15.3	14.4				
Sum					264.9	441.3	335.1	307.9

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dried at an initial temperature of 70 °C, and then dried at 105 °C to a constant weight using the SLW 115 SIMPLE dryer (Merazet, Poznań, Poland) with forced air circulation. The results of the three-year study were statistically calculated using the variance analysis method for two-factor experiments. The significance of differences between the objects was verified by the Tukey's test at the level of significance $P < 0.05$ (Trętowski and Wójcik 1991).

The humidity and thermal conditions in the years of research were varied (Table 2). In 2012, air temperature in individual months was close to the average from 1980–2009. Precipitation this season was lower by 33 mm, but was evenly distributed during the growing potato season, which contributed to the accumulation of nutrients. In 2013, the temperatures in May, June and August were higher than in the long-term period, and the rainfall was higher by 133.4 mm

Table 3. Content and yields of dry matter and starch in potato tubers

Methods of herbicides and biostimulants application	Cultivar			Mean
	Bartek	Gawin	Honorata	
Dry matter of potato tubers (g/kg)				
CO	217.8	244.8	247.7	236.8
H	213.5	246.0	248.9	236.1
H + K	218.0	246.5	249.5	238.0
S	216.7	250.0	250.0	238.9
S + A	219.1	251.5	250.7	240.5
Mean	217.0	247.8	249.4	238.1
$LSD_{0.05}$ for: cultivars – 2.5; methods – ns; interaction: cultivars × method – ns				
Starch (g/kg)				
CO	127.0	151.1	155.3	144.5
H	127.0	151.3	157.0	145.4
H + K	129.0	153.7	158.4	147.0
S	128.1	152.3	158.8	146.4
S + A	129.7	154.6	160.1	148.2
Mean	128.3	152.6	157.9	146.3
$LSD_{0.05}$ for: cultivars – 1.9; methods – 2.5; interaction: cultivars × methods – ns				
Tuber dry matter yield (t/ha)				
CO	7.40	8.06	8.57	8.01
H	8.16	9.05	10.17	9.13
H + K	9.07	9.91	10.64	9.87
S	9.39	10.36	11.56	10.44
S + A	9.90	10.87	11.88	10.88
Mean	8.79	9.65	10.56	9.67
$LSD_{0.05}$ for: cultivars – 0.53; methods – 0.53; interaction: cultivars × methods – ns				
Starch yield (t/ha)				
CO	4.43	4.99	5.37	4.93
H	4.79	5.61	6.41	5.61
H + K	5.38	6.16	6.75	6.10
S	5.57	6.30	7.33	6.40
S + A	5.89	6.67	7.59	6.72
Mean	5.21	5.95	6.69	5.95
$LSD_{0.05}$ for: cultivars – 0.33; methods – 0.3; interaction: cultivars × methods – ns				

LSD – least significant difference; ns – not significant; CO – control object; H – Harrier 295 ZC; H + K – Harrier 295 ZC + Kelpak SL; S – Sencor 70 WG; S + A – Sencor 70 WG + Asahi SL

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than in 1980–2009 and unevenly distributed. It was a rather humid year. The 2014 season was warmer than the long-term period, but rainfall during the growing months varied greatly. There was a significant humidity deficiency in July and an excess in August, i.e. in the months determining the increase in tuber weight and accumulation of ingredients in potatoes.

RESULTS AND DISCUSSION

The dry matter content of potato tubers averaged to 238.1 g/kg, while depending on the examined cultivar factors, methods of using herbicides and biostimulants, and atmospheric conditions in the year of research it ranged from 205.7 to 266.0 g/kg (Tables 3 and 4). The cultivars cultivated in the experiment differed significantly in the dry matter content in the tubers. Cv. Honorata had the largest amount, followed by cv. Gawin, whereas cv. Bartek had a significantly lesser amount. Different dry matter content depending on the cultivar was also shown by other authors (Mareček et al. 2013, Grudzińska et al. 2015, Manolov et al. 2016). In the performed studies, the dry matter content did not depend on the methods of herbicides and biostimulants application, while the effect of atmospheric conditions in the years of the study was observed. Most of dry matter was accumulated by all cultivars in 2012, which was the warmest, quite dry, but the rainfall was evenly distributed during the growing months. Hamouz et al. (2005), Macák et al. (2012) and Escuredo et al. (2018) showed that tubers harvested in the warm season, with the least amount of rainfall during vegetation, contained the most dry matter and starch.

Table 4. Content and yields of dry matter and starch in potato tubers in study years

Year	Cultivar			Mean
	Bartek	Gawin	Honorata	
Dry matter of potato tubers (g/kg)				
2012	239.3	266.0	264.0	256.4
2013	206.2	245.6	250.7	234.2
2014	205.7	231.7	233.4	223.6
Mean	217.0	247.8	249.4	238.1
$LSD_{0.05}$ for: cultivars – 2.5; years – 2.5; interaction: cultivars × years – 4.3				
Starch (g/kg)				
2012	145.4	166.1	164.5	158.7
2013	121.6	147.5	154.9	141.4
2014	117.9	144.3	154.3	138.8
Mean	128.3	152.6	157.9	146.3
$LSD_{0.05}$ for: cultivars – 1.9; years – 1.9; interaction: cultivars × years – 3.3				
Tuber dry matter yield (t/ha)				
2012	12.03	12.82	11.51	12.12
2013	7.36	8.35	10.22	8.64
2014	6.97	7.78	9.96	8.24
Mean	8.79	9.65	10.56	9.67
$LSD_{0.05}$ for: cultivars – 0.53; years – 0.53; interaction: cultivars × years – 0.92				
Starch yield (t/ha)				
2012	7.31	7.99	7.17	7.49
2013	4.29	4.98	6.30	5.19
2014	4.04	4.87	6.59	5.17
Mean	5.21	5.95	6.69	5.95
$LSD_{0.05}$ for: cultivars – 0.33; years – 0.33; interaction: cultivars × years – 0.57				

LSD – least significant difference; ns – not significant; CO – control object; H – Harrier 295 ZC; H + K – Harrier 295 ZC + Kelpak SL; S – Sencor 70 WG; S + A – Sencor 70 WG + Asahi SL

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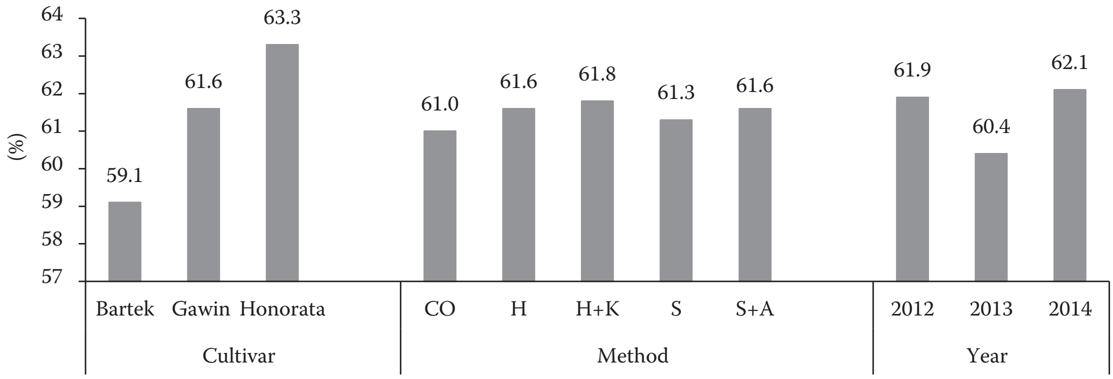

Figure 1. Percentage of starch in the tuber dry matter. CO – control object; H – Harrier 295 ZC; H + K – Harrier 295 ZC + Kelpak SL; S – Sencor 70 WG; S + A – Sencor 70 WG + Asahi SL

Cultivars, methods of using herbicides and biostimulants, and climatic conditions determined the starch content in tubers (Tables 3 and 4). Cv. Honorata had the highest concentration of starch compared to other cultivars. The influence of the cultivar on the content of this ingredient was demonstrated by Grudzińska et al. (2015), Manolov et al. (2016), and Leonel et al. (2017). The conducted research found a significant increase in the starch content after using herbicides with biostimulants (methods 3 and 5) compared to the control object. There has also been a tendency to increase the starch content in tuber dry matter after the application of herbicides and biostimulants (Figure 1). Beneficial effects of biostimulants on starch accumulation were also shown by other authors (Trawczyński 2018, Mystkowska 2019).

The size of tubers and starch dry matter yields is mainly determined by the weight of tubers harvested and the content of the ingredients discussed above. The obtained study results proved that the yield of tubers and starch dry matter were influenced by the cultivars cultivated in the experiment, methods of using herbicides and biostimulants, and meteorological conditions prevailing in individual years of the study (Tables 3 and 4, Figures 2 and 3). Cv. Honorata yielded the highest dry matter and starch tubers, while cvs. Gawin and Bartek gave significantly lower values. Herbicides and herbicides with biostimulants significantly increased the yields of these components, and the most favourable results were obtained after the joint application of the herbicide Sencor 70 WG and biostimulant Asahi SL in relation to the control object. The obtained results were confirmed by Baranowska (2018), who collected the largest dry matter and starch yields after using the herbicide Avatar 293 ZC and biostimulator GreenOK Universal-PRO.

The conducted research shows that weather conditions, interaction of cultivars with years and methods with years of research significantly affected the yield of dry matter and starch. The highest yields of these components were obtained in 2012 with favourable

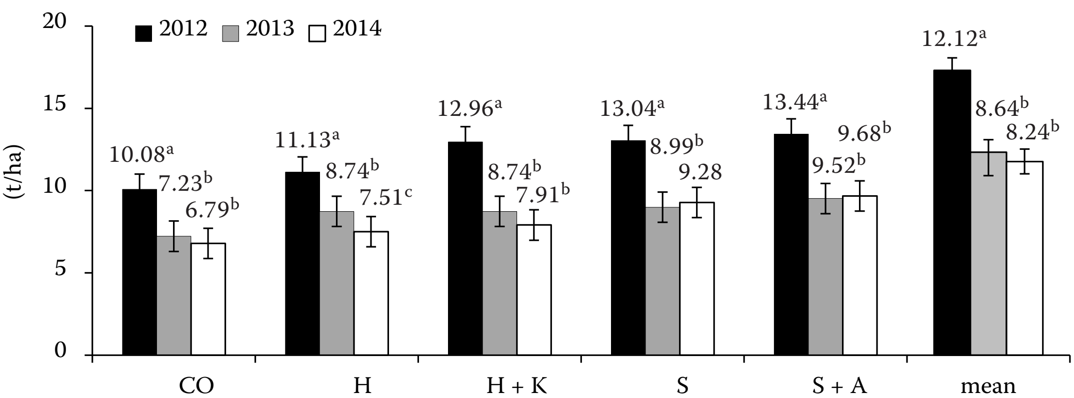

Figure 2. Tuber dry matter yield of potato depending on methods in years of study. *LSD* (least significant difference) at $P < 0.05$. Mean values followed by different letters (a, b, c) differ significantly at $P < 0.05$. CO – control object; H – Harrier 295 ZC; H + K – Harrier 295 ZC + Kelpak SL; S – Sencor 70 WG; S + A – Sencor 70 WG + Asahi SL

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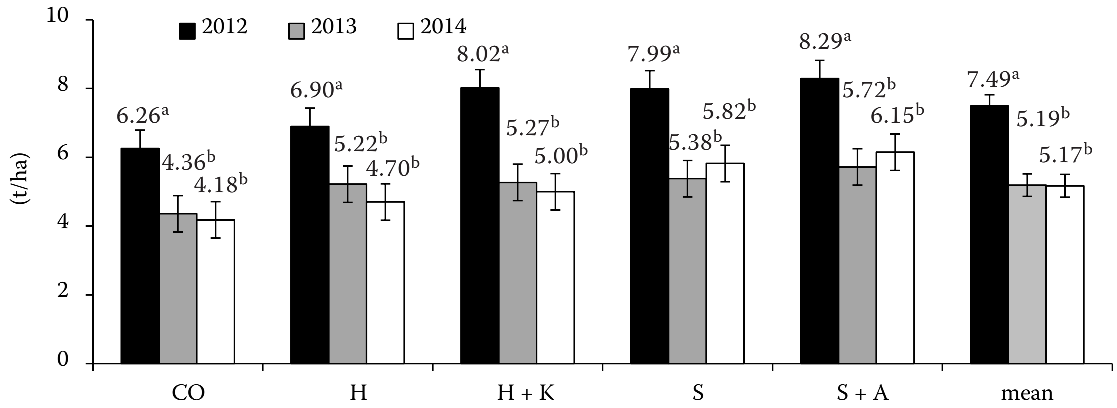

Figure 3. Tuber starch yield of potato depending on methods in years of study. *LSD* (least significant difference) at $P < 0.05$. Mean values followed by different letters (a, b, c) differ significantly at $P < 0.05$. CO – control object; H – Harrier 295 ZC; H + K – Harrier 295 ZC + Kelpak SL; S – Sencor 70 WG; S + A – Sencor 70 WG + Asahi SL

meteorological conditions during the potato growing season, while significantly lower in the other potato growing seasons.

The Commission Implementing Regulation (EU) 2017/244 of 10 February 2017 did not renew the approval of the use of the active substance linuron, and the grace period for using this active substance ended on June 3, 2018. Hence, the research results from the conducted experiment can only be used outside the European Union countries.

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