

THE INFLUENCE OF WEED CONTROL METHODS ON TOTAL PROTEIN AND TRUE PROTEIN IN POTATO TUBERS

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Abstract. Most quality characteristics of potato tubers are affected by an interplay of plant genetic traits and environmental factors, including weed control. As a result, detailed studies on plant responses to changing agrotechnological factors seem to be justified. It was attempted in the present work to determine the effect of weed control methods on total and true protein content in two kinds of table potato tubers. The field experiment was designed as a split-plot arrangement of the following two factors: potato cultivars: Irga and Balbina, and four weed control methods: 1 – mechanical weed control – control treatment, 2 – mechanical weed control + the herbicide Plateen 41.5 WG at the rate of $2.0 \text{ kg} \cdot \text{ha}^{-1}$, 3 – mechanical weed control + the herbicide Racer 250 EC at the rate of $3.0 \text{ dm}^3 \cdot \text{ha}^{-1}$, 4 – mechanical weed control + the herbicide Sencor 70 WG at the rate $1.0 \text{ kg} \cdot \text{ha}^{-1}$. The weed control methods examined in the study increased the total and true protein contents by an average of 0.04-0.14 and 0.02-0.06%, respectively. Compared with the control treatment, a significantly higher total protein content was found in treatment 3, where a combination of mechanical and chemical control had been applied (one hilling + spraying with Racer 250 EC at the rate of $3.0 \text{ dm}^3 \cdot \text{ha}^{-1}$ 10 days after planting), and in treatment 4, where mechanical and chemical control had been applied, too (two hillings combined with harrowing before emergence of potato plants + Sencor 70 WG at the rate of $1.0 \text{ kg} \cdot \text{ha}^{-1}$ applied just before emergence. The highest true protein content was determined when weeds were controlled mechanically and chemically using Sencor 70 WG. The study results demonstrated that Irga had a higher concentration of total protein and true protein, on average 9.89 and 6.70%, respectively, compared with Balbina (9.11 and 6.44%, respectively). The weather conditions in the study years significantly affected the total and true protein contents which were the highest in 2007 when the temperature was the most suitable for potato development.

Key words: atmospheric conditions, total protein, true protein, variety, weed control methods

INTRODUCTION

In potato production for food and industrial purposes, the content of the basic nutrients, such as dry matter, starch, protein, is as important as the amount of produced biomass. Irrespective of the way of potato tuber utilization, the quality characteristics determine their final destination [Puła and Skowera 2004, Krzysztofik *et al.* 2005].

Protein present in potato tubers has a high biological value. It contains all the exogenous amino acids which the human organism cannot synthesize. It is compared with soybean protein and it only slightly less than the nutritional standard, which the chicken egg white is assumed to be. Moreover, as one of few plant proteins, it is similar to the value of animal protein in its biological value [Kolasa 1993, Pęksa 2003, Sawicka 2003].

Most quality features of potato tubers are dependent on the combined effect of genetic traits of this plant with environmental factors, i.e. mineral fertilization, tillage, the level of protection against weeds, pests and diseases and the meteorological conditions in individual growing seasons [Leszczyński 2002, Makaravičiute 2003, Sądej *et al.* 2004, Gugala *et al.* 2007]. Therefore it is justified to test the plant response, particularly their quality features, on changing agrotechnological factors.

The aim of this study was to estimate the effect of cultivation methods on the content of total and true protein in tubers of two table potato cultivars.

MATERIAL AND METHODS

The results of the study derive from the field experiment conducted in 2005-2007 at the Agricultural Experimental Station Zawady (52°03' N; 22°33' E), owned by the Siedlce University of Natural Sciences and Humanities. The two-factorial experiment was established in the split-plot design with three replications: I factor – two potato cultivars: Irga and Balbina, II factor – four weed control methods:

- mechanical weed control, i.e. two – three hillings combined with harrowing before emergence of potato plant, hilling after emergence before row closeness – control treatment,
- mechanical and chemical control, i.e. two hillings combined with harrowing before emergence, and hilling + herbicide Plateen 41,5 WG (flufenacet 24% + metrybuzin 17.5%) at the rate 2.0 kg·ha⁻¹ just before emergence,
- mechanical and chemical control, i.e. one hilling and spraying with herbicide Racer 250 EC (flurochloridon 250 g) at the rate 3.0 dm³·ha⁻¹, until 10 days after potato planting,
- mechanical and chemical control, i.e. two hillings combined with harrowing before emergence, and one hilling + herbicide Sencor 70 WG (metrybuzin 70%) at the rate of 1.0 kg·ha⁻¹ applied just before emergence.

The field experiment was established in the soil classified as the division – autogenic soils, order – brown earth soils, type – Alfisols formed from light loamy sands and heavy loamy sands, soil quality classes IVa and IVb, classified as the very good rye complex in respect of agricultural usefulness. Potato was cultivated in the field after winter cereals. Constant fertilization was applied in the experiment: organic, with 25 t·ha⁻¹ of stable manure, and mineral, in the amounts: 90 kg·ha⁻¹ of N, 32.9 kg·ha⁻¹ of

P and 112.1 kg·ha⁻¹ of K. Potatoes were harvested at the technological maturity stage in the first ten days of September. Samples of potato tubers for chemical analyses were collected from the plots during harvesting. Initially prepared samples (cleaned and mixed) were stored until the moment of performing chemical analyses (two days) in paper bags at 18-20°C.

Chemical analyses were performed in dry material. The content of total and true protein was calculated from the content of total and protein nitrogen, using the index 6.25. Total and protein nitrogen was determined with the Kjeldahl method on the apparatus 2300 Kjeltec Analyzer Unit [Ostrowska *et al.* 1991].

The results of the study were subjected to the statistical analysis with the method of the analysis of variance. Significance of variability sources was tested with the Fisher-Snedecor 'F' test, and the evaluation of the significance of differences at the significance level $P = 0.05$ between the compared means using Tukey's multiple intervals [Trętowski and Wójcik 1988].

The weather conditions in the years of conducting the study were varied and they are presented in Table 1. In 2005 the total precipitation was 268.8 mm and according to the calculated Sielianinov coefficient, the growing season was characterized by the absence of drought. However, there were months with extreme conditions – from heavy drought in April and September to the absence of drought in May and July. The growing season of 2006 was also characterized by the lack of drought. Precipitation was the highest and it exceeded the average total from the long-term period, but it was unevenly distributed. The lowest was observed in June and July – the months determining the development, yield and accumulation of nutrients in potato tubers. The year 2007 in turn, when the total precipitation amounted to 308.2 mm, was the most favourable for potato growth. According to the hydrothermal coefficient, the atmospheric conditions in individual months were different, but uniformly distributed.

RESULTS AND DISCUSSION

One of the components of potato tubers is protein, with the content of about 2%, of which true protein accounts for 35-65%. The present study indicated that the concentration of total and true protein significantly depended on the control method, the cultivars grown and the weather conditions prevailing in individual years of the study (Table 2 and 3). Mechanical and chemical control applied in the experiment resulted in an increase in total protein content on average from 0.04 to 0.14% and in true protein from 0.02 to 0.06%. Significantly higher content of total protein in comparison with the control variant was observed on the plots where mechanical and chemical control was applied, i.e. one hilling and spraying with herbicide Racer 250 EC at the rate 3.0 dm³·ha⁻¹ until 10 days after potato planting, and where mechanical and chemical control applied included two hillings combined with harrowing before emergences, and hilling + herbicide Sencor 70 WG at the rate 1.0 kg·ha⁻¹ just before emergence.

Table 1. Weather conditions in potato vegetation period in 2005-2007
 Tabela 1. Warunki meteorologiczne w okresie wegetacji ziemniaka w latach 2005-2007

Year – Rok	Month – Miesiąc					Mean April – September Średnia kwiecień – wrzesień
	April kwiecień	May maj	June czerwiec	July lipiec	August sierpień	
	Temperature – Temperatura, °C					
2005	8.7	13.0	15.9	20.2	17.5	15.0
2006	8.4	13.6	17.2	22.3	18.0	15.4
2007	8.6	14.6	18.2	18.9	19.9	15.4
Multiyear mean Średnia z wielolecia 1987-2000	7.8	12.5	17.2	19.2	18.5	14.7
	Rainfall – Opady, mm					Sum April – September Suma kwiecień – wrzesień
2005	12.3	64.7	44.1	86.5	45.4	268.8
2006	29.8	39.6	24.0	16.2	228.1	358.6
2007	21.2	59.1	59.0	70.2	31.1	308.2
Multiyear sum Suma z wielolecia 1987-2000	38.6	44.1	52.4	49.8	43.0	275.2
	Sielianinov's hydrothermic coefficients – Współczynnik hydrotermiczny Sielianinowa*					Mean April – September Średnia kwiecień – wrzesień
2005	0.47	1.60	0.92	1.51	0.84	1.00
2006	1.18	0.99	0.47	0.24	4.18	1.26
2007	0.82	1.37	1.08	1.23	0.53	1.10

* value of Sielianinov's coefficient – wartość współczynnika Sielianinowa [Bac i in. 1998]
 < 0.5 – strong drought – silna posucha, 0.51-0.69 – drought – posucha, 0.70-0.99 – weak drought – słaba posucha, ≥ 1 – absence of drought – brak posuchy

Mechanical and chemical control in which herbicide Sencor 70 WG was applied had also a significant effect on the true protein content. In this variant an increase in the component in question on average by 0.06% was observed, as compared with only mechanical control applied. These results are similar to the study by Ceglarek and Książak [1992], Sawicka and Kuś [2002], Zarzecka and Gugała [2006] as well as Rymuza et al. [2013], who proved that the content of total and true protein was affected by control methods on the plantation and the concentrations of those components were higher in tubers derived from variants treated with herbicides, as compared with potatoes collected from control plots where only mechanical control was applied. Also the study by Wichrowska *et al.* [2009] indicated that tubers collected from the variants sprayed with herbicides during the plant growth period contained by 3.7% more protein than the tubers of plants controlled only mechanically.

Table 2. Content of total protein in the dry matter of potato tubers, %
Tabela 2. Zawartość białka ogólnego w suchej masie bulw ziemniaka, %

Cultivar Odmiana	Weed control methods Sposoby pielęgnacji	Year – Rok			Mean Średnia
		2005	2006	2007	
Irga	1) control treatment – obiekt kontrolny*	9.80	9.52	10.14	9.82
	2) Plateen 41,5 WG	9.86	9.55	10.16	9.86
	3) Racer 250 EC	9.97	9.82	10.17	9.98
	4) Sencor 70 WG	9.91	9.70	10.16	9.92
	Mean – Średnia	9.88	9.65	10.15	9.89
Balbina	1) control treatment – obiekt kontrolny	9.37	8.29	9.49	9.05
	2) Plateen 41,5 WG	9.45	8.32	9.52	9.09
	3) Racer 250 EC	9.46	8.46	9.57	9.16
	4) Sencor 70 WG	9.43	8.45	9.55	9.14
	Mean – Średnia	9.42	8.38	9.53	9.11
Mean Średnia	1) control treatment – obiekt kontrolny	9.58	8.90	9.81	9.43
	2) Plateen 41,5 WG	9.65	8.94	9.84	9.48
	3) Racer 250 EC	9.71	9.14	9.87	9.57
	4) Sencor 70 WG	9.67	9.08	9.85	9.53
Mean for years – Średnio dla lat		9.65	9.01	9.84	–
LSD _{0.05} – NIR _{0.05} for – dla:					
years – lat		0.12			
cultivars – odmian		0.07			
weed control methods – sposobów pielęgnacji		0.07			
interaction – interakcji:					
weed control methods × cultivars – sposoby pielęgnacji × odmiany				ns – ni	
weed control methods × years – sposoby pielęgnacji × lata				ns – ni	
cultivars × years – odmiany × lata				ns – ni	

* 1) control object – mechanical weeding – obiekt kontrolny – pielęgnacja mechaniczna, 2) mechanical weeding + Plateen 41,5 WG 2,0 kg·ha⁻¹ – pielęgnacja mechaniczna + Plateen 41,5 WG 2,0 kg·ha⁻¹, 3) mechanical weeding + Racer 250 EC 3,0 dm³·ha⁻¹ pielęgnacja mechaniczna + Racer 250 EC 3,0 dm³·ha⁻¹, 4) mechanical weeding + Sencor 70 WG 1,0 kg·ha⁻¹ – pielęgnacja mechaniczna + Sencor 70 WG 1,0 kg·ha⁻¹
ns – ni – non-significant differences – różnice nieistotne

Table 3. Content of true protein in the dry matter of potato tubers, %
 Tabela 3. Zawartość białka właściwego w suchej masie bulw ziemniaka, %

Cultivar Odmiana	Weed control methods Sposoby pielęgnacji	Year – Rok			Mean Średnia
		2005	2006	2007	
Irga	1) control treatment – obiekt kontrolny*	6.66	6.63	6.73	6.67
	2) Plateen 41,5 WG	6.70	6.65	6.75	6.70
	3) Racer 250 EC	6.69	6.65	6.74	6.69
	4) Sencor 70 WG	6.71	6.69	6.76	6.72
	Mean – Średnia	6.69	6.66	6.74	6.70
Balbina	1) control treatment – obiekt kontrolny	6.42	6.33	6.45	6.40
	2) Plateen 41,5 WG	6.44	6.40	6.49	6.44
	3) Racer 250 EC	6.45	6.38	6.47	6.43
	4) Sencor 70 WG	6.49	6.41	6.55	6.48
	Mean – Średnia	6.45	6.38	6.49	6.44
Mean Średnia	1) control treatment – obiekt kontrolny	6.54	6.48	6.59	6.54
	2) Plateen 41,5 WG	6.57	6.52	6.62	6.57
	3) Racer 250 EC	6.57	6.51	6.60	6.56
	4) Sencor 70 WG	6.60	6.55	6.66	6.60
	Mean for years – Średnio dla lat	6.57	6.52	6.62	–
LSD _{0.05} – NIR _{0.05} for – dla:					
years – lat		0.03			
cultivars – odmian		0.02			
weed control methods – sposobów pielęgnacji		0.04			
interaction – interakcji:					
weed control methods × cultivars – sposoby pielęgnacji × odmiany				ns – ni	
weed control methods × years – sposoby pielęgnacji × lata				ns – ni	
cultivars × years – odmiany × lata				ns – ni	

for explanation, see Table 2 – objaśnienia pod tabelą 2

According Marks *et al.* [2005], Wichrowska *et al.* [2009], Kołodziejczyk *et al.* [2010] and Wierzbička and Trawczyński [2012], the content of protein in potato tubers are determined by the genetic properties of the cultivars.

The results of the present study proved that among the grown cultivars the cultivar Irga was characterized by a higher concentration of total protein - on average 9.89% and true protein – on average 6.70%, whereas the cultivar Balbina contained significantly less – 9.11% and 6.44%, respectively, which was confirmed in the studies of the authors mentioned above.

Kraska [2002] as well as Mazurczyk and Lis [2001] report about the effect of the weather conditions on protein content. Atmospheric conditions in the years of the study significantly differentiated both the content of total and true protein (Table 2 and 3). The highest amount of the component in question was accumulated by tubers harvested in 2007, where the average air temperature in July amounted to 18.9°C, and the total precipitation 70.2 mm. The lowest content of total and true protein occurred in tubers collected in 2006, which was characterized by the highest air temperatures in July and the lowest precipitation.

These results were confirmed in the study conducted by Puła and Skowera [2004], which indicate that tubers collected in the year with the highest total precipitation were characterized by the largest amount of protein, whereas the smallest amount of the component in question was obtained in the season with the lowest total precipitation.

Marks *et al.* [2005] in turn obtained the least protein in the year when the highest precipitation occurred. The effect of the weather conditions during the growth season on protein content in potato tubers is also reported by Zrůst and Hola [1994], Lachman *et al.* [2005] as well as Zarzecka and Gugała [2006].

CONCLUSIONS

1. Mechanical and chemical cultivation contributed to an increase in total and true protein content in potato tubers. The highest content of total protein – on average 9.57% in dry matter of tubers was obtained in the variant where a single ridging + the herbicide Racer 250EC were applied, while true protein on average 6.80% on plots with mechanical and chemical cultivation with the use of the preparation Sencor 70WG

2. The cultivar Irga was characterized by a higher concentration of total and true protein in tubers than the cultivar Balbina.

3. The highest concentration of total and true protein in potato tubers was obtained in 2007, which was characterized by the most optimal precipitation and air temperature for potato growth.

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WPLYW SPOSOBÓW PIELĘGNACJI NA ZAWARTOŚĆ BIAŁKA OGÓLNEGO I WŁAŚCIWEGO W BULWACH ZIEMNIAKA

Streszczenie. Większość cech jakościowych bulw ziemniaka uzależniona jest od współdziałania cech genetycznych tej rośliny z czynnikami środowiskowymi, w tym z poziomem ochrony przed chwastami. Celowe jest więc prowadzenie szczegółowych badań dotyczących reakcji roślin na zmieniające się czynniki agrotechniczne. W pracy określono wpływ stosowanych sposobów pielęgnacji na zawartość białka ogólnego i właściwego w bulwach dwóch odmian ziemniaka jadalnego. Doświadczenie polowe założono w układzie split-plot jako dwuczynnikowe w trzech powtórzeniach: I czynnik –

dwie odmiany ziemniaka: Irga i Balbina, II czynnik – cztery sposoby pielęgnacji: 1) pielęgnacja mechaniczna – wariant kontrolny, 2) pielęgnacja mechaniczna + herbicyd Plateen 41,5 WG w dawce $2,0 \text{ kg} \cdot \text{ha}^{-1}$, 3) pielęgnacja mechaniczna + herbicyd Racer 250 EC w dawce $3,0 \text{ dm}^3 \cdot \text{ha}^{-1}$, 4) pielęgnacja mechaniczna + herbicyd Sencor 70 WG w dawce $1,0 \text{ kg} \cdot \text{ha}^{-1}$. Zastosowane w doświadczeniu sposoby pielęgnacji powodowały wzrost zawartości białka ogólnego średnio od 0,04 do 0,14%, a białka właściwego od 0,02 do 0,06%. Istotnie większą zawartość białka ogólnego w porównaniu z wariantem kontrolnym stwierdzono w bulwach rosnących na poletkach, na których zastosowano pielęgnację mechaniczno-chemiczną, tj. jednokrotne obredlanie i do 10 dni po posadzeniu ziemniaków opryskiwanie herbicydem Racer 250 EC w dawce $3,0 \text{ dm}^3 \cdot \text{ha}^{-1}$ oraz tam, gdzie stosowano pielęgnację mechaniczno-chemiczną, tj. do wschodów dwukrotne obredlanie połączone z bronowaniem, a tuż przed wschodami obredlanie + herbicyd Sencor 70 WG w dawce $1,0 \text{ kg} \cdot \text{ha}^{-1}$. Największą zawartość białka właściwego uzyskano natomiast stosując pielęgnację mechaniczno-chemiczną z użyciem herbicydu Sencor 70 WG. Wyniki badań dowiodły, że odmiana Irga charakteryzowała się większą koncentracją białka ogólnego – średnio 9,89% i białka właściwego – średnio 6,70% niż odmiana Balbina, odpowiednio: 9,11 i 6,44%. Warunki atmosferyczne w latach prowadzenia badań istotnie różnicowały zarówno zawartość białka ogólnego, jak i właściwego. Największą ilość omawianych składników nagromadziły bulwy zebrane w 2007 roku, charakteryzującym się najbardziej optymalną dla rozwoju ziemniaka ilością opadów i temperaturą.

Słowa kluczowe: białko ogólne, białko właściwe, odmiany, sposoby pielęgnacji, warunki atmosferyczne

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