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ORIGINAL PAPER

EFFECT OF HERBICIDES AND THEIR APPLICATION DATES ON THE CONTENT OF PHOSPHORUS, POTASSIUM AND TOTAL NITROGEN IN POTATO TUBERS*

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Abstract

The aim of the study was to determine the impact weed infestation control technologies on the mineral composition of potato tubers. The results of the research originated from a field experiment conducted in 2007-2009 at the Plant Breeding and Acclimatization Institute – National Research Institute in Jadwisin (52°29′N, 21°03′E). The experiment was designed with the method of random subblocks in a dependent system of split-plots, in three replications. Two factors were included: the first factor composed of potato cultivars, Irga and Fianna, and the second one comprising weed control methods: 1) control – without chemical protection, mechanical treatments; 2) extensive (every 2 weeks) from planting to row compaction; 3) Sencor 70 WG – 1 kg ha^{-1} pre-emergence potato; 4) Sencor 70 WG – 1 kg ha^{-1} + Titus 25 WG – 40 g ha^{-1} + Trend 90 EC – 0.1% prior to the emergence of potato; 5) Sencor 70 WG – 0.5 kg ha^{-1} after the emergence of potato; 6) Sencor 70 WG – 0.3 kg ha^{-1} + Titus WG 25 – 30 g ha^{-1} + Trend 90 EC – 0.1% after the emergence of potato; 7) Sencor 70 WG – 0.3 kg ha^{-1} + Fusilade Forte 150 EC – 2 dm^3 ha^{-1} after the emergence of potato; 8) Sencor 70 WG – 0.3 kg ha^{-1} + Apyros 75 WG 26.5 g ha^{-1} + Atpolan 80 SC – 1 dm^3 ha^{-1} after the emergence of potato. After harvesting, the fresh weight of tubers assayed nitrogen, phosphorus and potassium according to the adopted methods. The use of herbicides to regulate weeds increased the content of nitrogen and phosphorus, and the amount of potassium was not dependent on the herbicides used and the timing of their application. Meteorological conditions had a significant effect on the content of nitrogen and potassium, the higher their accumulation was found in the dry year, the lowest in the year with a higher amount of rainfall and lower amplitude of air temperatures.

Keywords: herbicides, cultivars, tuber mineral composition, macroelements, nutritional value.

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INTRODUCTION

The nutritional value of potato tubers, apart from proteins, carbohydrates and vitamins, is also determined by the content of minerals which, after digestion and absorption into the blood, are used by an organism as building material or a factor regulating life processes (Zarzecka et al. 2013, Andre et al. 2014). Many studies show that herbicidal formulations affect the metabolism of plants, both weeds and protected plants (Zarzecka et al. 2013, Gugała et al. 2015, Płaza et al. 2017). This, in turn, can cause chemical changes in the composition of tubers. Relationships between of weed infestation and content of macro- and micronutrients in yields of crops are an essential problem because a weed and crop system depends not only on the competition for habitat resources, but is also affected by allelopathic effects that cause changes in the volume and chemical composition of crop yields, e.g. potato tubers (Różyło, Pałys 2009). Therefore, the aim of this study was to determine the impact of herbicides used in the experiment on the mineral composition of potato tubers. It was assumed that the herbicides applied to control weed infestation of potato, especially mixtures of preparations (Sencor 70 WG + Titus + Trend 90 EC, Sencor 70 WG + Fusilade Forte 150 EC, Sencor 70 WG + Apyros 75 WG + Atpolan 80 SC) would not only provide a larger spectrum of chemical action resulting in better weed control, but could also ensure a larger yield of tubers, whereas the application of smaller doses might reduce environmental contamination, ensure better cost-effectiveness of mechanical treatments and would have a beneficial effect on the tubers' mineral composition and nutritional value.

MATERIAL AND METHODS

Results of the research were based on a field experiment carried out in 2007-2009 at the Plant Breeding and Acclimatization Institute – National Research Institute in Jadwisin (52°29′N, 21°03′E), on Podzolic soil with the particle size composition of light loamy sand, good rye complex, soil valuation class IVb (WRB 2014). The experiment was established using a random sub-block method in a dependent split-plot system, in triplicate. Two factors were investigated in the experiment: 1st order factors were potato cultivars: Irga and Fianna, and 2nd order factor were ways to regulate weed infestation: 1) control object – without chemical protection; 2) extensive mechanical treatments (every 2 weeks) from planting to row compaction; 3) Sencor 70 WG – 1 kg ha^{-1} before the potato emergence; 4) Sencor 70 WG – 1 kg ha^{-1} + Titus 25 WG – 40 g ha^{-1} + Trend 90 EC – 0.1% before the potato emergence; 5) Sencor 70 WG – 0.5 kg ha^{-1} after the potato emergence; 6) Sencor 70 WG – 0.3 kg ha^{-1} + Titus 25 WG – 30 g ha^{-1} + Trend 90 EC – 0.1% after the potato emergence; 7) Sencor 70 WG – 0.3 kg ha^{-1} + Fusilade Forte 150 EC – 2 dm^{3} ha^{-1} after the potato emergence; 8) Sencor 70 WG – 0.3 kg ha^{-1} + + Apyros 75 WG 26.5 g ha^{-1} + Atpolan 80 SC – 1 dm^{3} ha^{-1} after the potato emergence. 400 dm ha^{-1} water was used to spray the plants with herbicides. To perform the treatments, a battery sprayer was used, equipped with flat-spray nozzles with an outflow rate of 0.35-0.65 dm^{3} min^{-1} and pressure of 0.1-0.2 MPa.

Herbicide active substances

Metribuzin was used in the form of Sencor 70 WG, sulfosulfuron – in the form of Apyros 75 WG; rimsulfuron – in the form of the herbicide Titus 25 WG; Fluazyfop – in the form of Fusilade Forte 150 EC. The characteristics of herbicides and adjuvants are given in Table 1.

Table 1

Characteristics of the herbicides and herbicide additives used in the experiment

Trade names of the preparation	Active substances	Content of active substances	Recommended application rates per 1 ha	Utility forms	Grace period
Herbicides					
Apyros 75WG	sulfosulfuron	(75%)	26.5 g	granules for water suspension	not applicable
Fusilade Forte 150 EC	fluazyfop-P butyl	150 g in 1 dm^{3} of measure	0.5-2.5 dm^{3}	concentrate for water suspension	not applicable
Sencor 70 WG	metribusin	70%	0.5-1 kg	granules for water suspension	42 days
Titus 25 WG	rimsulfuron	25%	30-60 g	granules for water suspension	not applicable
Adjuvants (boosters)					
Atpolan 80 SC	SN oil	76%	1.5 dm^{3}	concentrate for water suspension	not applicable
Trend 90 EC	ethoxylated isodecyl alcohol	90%	0.05-0.1% (50-100 ml 100 dm^{-3} wather)	concentrate for water suspension	not applicable

Sources: developed bu the authors, based on: Korbas et al. (2017) and Tomlin (2011)

Cultivation treatments

The preceding crop of potato was winter wheat, after harvesting of which the catch crop of white mustard for plowing was used. After the wheat harvest, nitrogen fertilization in the amount of 50 kg N ha^{-1} was applied, followed by stubble cultivation and sowing of white mustard in the amount of 20 kg ha^{-1}. In autumn each year, before sowing, mineral phosphorus-potassium fertilization in the amount of 39.3 kg P and 116.3 kg K ha^{-1} was used, which was plowed with pre-winter plowing. Nitrogen fertilizers were sown in the spring, in the amount of 100 kg N ha^{-1}, and then they were mixed with the soil using a cultivating unit (cultivator + string roller). Potato tubers were planted manually, at the end of April, at spacing of 75 × 33 cm. The harvest of tubers was carried out with an elevator digger, at the end of September. During harvest, tuber samples for chemical analysis were taken from each plot (Roztropowicz 1999).

Chemical analyzes

In the dry mass of tubers, the following parameters were determined: nitrogen content by the Kjeldahl method (Simmone et al. 2008), phosphorus by the colorimetric, vanadate-molybdate method (Varley 1996), and potassium by atomic absorption spectrophotometry (Rutkowska, Trzebska-Jaske 1978).

Soil assesssment

Every year before launching the experiment, in accordance with PN-R-04031 (1997), 20 primary soil samples were collected from the arable layer (0-20 cm) to make a composite sample, weighing approx. 0.5 kg. These samples were tested to determine the particle size composition of the soil, the soil's richness in available phosphorus, potassium and magnesium, as well as the soil pH (WRB, 2014). Chemical and physicochemical properties of the soil were determined in a certified laboratory of the District Chemical and Agricultural Station in Wesoła near Warsaw, with the following methods:

– soil particle size composition was determined by laser diffraction (Ryzak et al. 2009);
– pH: in a suspension of 1 mol KCl dm^{-3} and in H_2O suspension with the potentiometric method (Lützenkirchen et al. 2012);
– organic carbon content Corg. – with the Tiurin method (KQ /PB-34);
– available magnesium content with the Schachtschabel method (PN-R-04020: 1994 + AZ1: 2004);
– content of absorbable forms of phosphorus and potassium with the Egner-Riehm method (PN-R-04023: 1996; PN-R-04022: 1996 + AZ1: 2002).

The results of soil analyses were confronted with standard values provided by the Soil Science and Plant Cultivation – National Research Institute (Nawrocki 1990).

Meteorological conditions

The weather conditions during the growing season in 2007-2009 were characterized by changeable air temperatures and rainfalls (Table 2). The values of the Selyaninov's hydrothermal coefficient are calculated from the formula (Skowera et al. 2014):

$$k = \frac{10P}{\sum t},$$

where:

P – sum of monthly precipitation in mm,

Σt – monthly total air temperature >0°C.

According to the Selyaninov's hydrothermal coefficient, the potato vegetation period was classified as wet (2007), dry (2008) and optimal (2009). In 2007, drought was recorded in April and July, while the remaining months were humid. The year 2008 was characterized by an optimal moisture content, but in June, during the period of intensive harvesting, dry conditions prevailed. In 2009, during potato planting and harvest, drought was recorded, while in the remaining months of the growing season were moist.

Table 2

Selyaninov's hydrothermal coefficients during the potato vegetation period in 2007-2009 according to the meteorological station in Jadwisin

Month	Years		
	2007	2008	2009
April	0.6	1.3	0.0
May	1.9	1.6	2.1
Juni	2.3	0.8	1.3
July	0.9	1.2	1.2
August	1.3	1.4	1.5
September	3.2	1.4	0.4

Source: date form meteorological station in Jadwisin

Ranges of values of this index were classified according to the Selyaninov's coefficient as: extremely dry – $k \leq 0.4$, very dry – $0.4 < k \leq 0,7$, dry – $0.7 < k \leq 1.0$, fairly dry – $1.0 < k \leq 1.3$, optimum – $1.3 < k \leq 1.6$, fairly humid – $1.6 < k \leq 2.0$, wet – $2.0 < k \leq 2.5$, very humid – $2.5 < k \leq 3.0$, extremely humid – $k > 3.0$ (Skowera et al. 2014).

Statistical calculations

Results of the research were statistically analyzed using the analysis of variance ANOVA SAS 2008. The significance of the variation sources was tested by the Fischer-Snedecor F test and the significance of differences between the tested means compared was assessed with the Tukey intervals. These tests ensured detailed comparative analysis of the means by isolating statistically homogeneous groups and determining the least significant mean differences, which in the Tukey's tests are denoted as HSD – Tukey's Honest Significant Difference (CROSSA, FRANCO 2004).

RESULTS AND DISCUSSION

The results of analyses of soil particle size composition and some physicochemical properties of soil are presented in Table 3. The experiment was carried out on sandy loam soil. According to the percentages of sand, silt and loam fraction, this was clay sand (light soil). Soil particle size composition was determined with the aerometric method, according to RYŻAK et al. (2009). The fractions of sand, silt and loam were 66.97%, 30.58% and 2.45%, respectively (Table 3).

Table 3

The particle size composition of soil

Year	Composition content of the granulometric fractions (%)									Soil classification
	sand					silt			loam	
	(mm)									
	2.0-1.0	1.0-0.5	0.5-0.25	0.25-0.10	0.10-0.05	0.05-0.02	0.02-0.005	0.005-0.002	< 0.002	
2007	0.10	16.50	29.64	12.05	8.61	16.02	11.10	3.37	2.61	sandy loam
2008	0.98	17.94	28.19	11.75	8.33	15.40	11.23	3.49	2.69	sandy loam
2009	0.71	15.09	25.39	13.59	21.05	18.48	10.27	2.37	2.05	sandy loam
Average	0.60	16.51	27.74	12.50	12.66	16.63	10.87	3.08	2.45	

Source: the authors, based on determinations at the Chemical-Agricultural Station in Wesoła near Warsaw

This distribution of individual fractions corresponds to the composition of clayey silt. In terms of agricultural suitability, such soils belong to slightly acidic good rye complex. The soil in our experiment was classified as light mineral soil (KABAŁA 2014, WRB 2014).

Soil reaction ranged from acidic (4.7 pH) to slightly acidic (5.4 pH). The content of organic matter in the arable layer was low and ranged from 6.8 to 7.3 g kg^{-1}. The soil phosphorus content was from very low (2009) to very high (2007). Soil abundance in available forms of potassium was also characterized by considerable variability in the years of our study, from low to high (61-184 mg K kg^{-1} soil). The magnesium content was moderate in the soil sampled in 2009 (36 mg Mg kg^{-1}), but very high – in 2007 (121 mg Mg kg^{-1}) – Table 4.

Studies reported by TAN et al. (2006), SAWICKA, BARBAŚ (2007), PŁAZA et al. (2017), and WIERZBOWSKA et al. (2018) implicate that herbicidal formulations affect the metabolism of plants, both weeds and protected plants. This may cause changes in the chemical composition of crops, e.g. potato tubers

Table 4

Physical and chemical properties of soil in Jadwisin (2007-2009)

Years	Content of assimilable macronutrients (mg kg^{-1} soil)			pH (1M KCl)	Corg (g kg^{-1})
	P	K	Mg		
2007	104.0	184.0	121.0	4.7	7.3
2008	43.0	139.0	93.0	5.4	6.8
2009	17.0	61.0	36.0	5.0	7.0
Mean	55.0	128.0	83.0		7.0

Source: the authors, based on determinations at the Chemical-Agricultural Station in Wesoła near Warsaw

(Richardson et al. 2004, Sawicka, Barbaś 2007, Gugała et al. 2015, Sawicka et al. 2015). The content of nitrogen in potato tubers in this experiment depended on both a cultivar and plant protection technology (Table 5).

Table 5

The effect of weed control methods, cultivars and years of cultivation on the total nitrogen content in the dry mass of potato tubers (g kg^{-1})

Experimental factors		Methods of weed control								Mean
Cultivar	year	1	2	3	4	5	6	7	8	
Irga	2007	16.26	18.36	18.10	19.36	18.43	18.76	18.13	19.66	18.38
	2008	11.73	11.90	12.56	12.86	13.16	14.10	13.56	14.13	13.00
	2009	15.00	17.63	17.96	19.00	17.10	18.56	17.56	18.30	17.63
	mean	14.33	15.96	16.20	17.07	16.23	17.14	16.41	17.36	16.33
Fianna	2007	23.83	20.73	21.06	20.30	2.040	20.90	20.90	21.00	21.14
	2008	11.50	11.50	13.06	12.23	1.276	12.93	11.56	11.63	12.14
	2009	12.93	14.66	20.56	17.50	2.066	21.43	15.56	14.70	17.25
	mean	16.08	16.63	18.22	16.67	1.794	18.42	16.01	15.77	16.84
Mean for years	2007	20.04	19.68	19.58	19.83	19.41	19.83	19.51	20.33	19.77
	2008	11.61	11.70	12.81	12.54	12.96	13.51	12.56	12.88	12.57
	2009	13.96	16.14	19.26	18.25	18.88	19.99	16.56	16.50	17.44
Mean		15.84	17.21	16.87	17.08	17.78	16.21	16.57	16.59	16.59

$LSD_{0.05}$ cultivars – 0.15, weeding – 0.48, year – 0.22, weeding x cultivar − n.s., cultivar x year – n.s., weeding x year, n.s. – non significante differences;

1 – control object, without weed control;

2 – mechanical care;

3 – Sencor 70 WG −1 kg ha^{-1} – before the emergence of the potato;

4 – Sencor 70 WG – 0.3 kg ha^{-1} + Titus 25 WG – 40 g ha^{-1} + Trend 90 EC – 0.1% before emergence of potato;

5 – Sencor 70 WG – 0.5 kg ha^{-1} – after potato emergence;

6 – Sencor 70 WG – 0.3 kg ha^{-1} + Titus 25 WG – 30 g ha^{-1} + Trend 90 EC – 0.1% after emergence of the potato;

7 – Sencor 70 WG – 0.3 kg ha^{-1} + Fusilade Forte 150 EC – 2 dm^{-3} ha^{-1} after potato emergence;

8 – Sencor 70 WG – 0.3 kg ha^{-1} + Apyros 75 WG 26.5 g ha^{-1} + Atpolan 80 SC – 1 dm^3 ha^{-1} after emergence of potato.

A higher concentration of this nutrient was recorded in potato tubers originating from the plots where chemical method of weed regulation was applied than from plots with mechanical weeding. The highest content of this element in tubers was found under the treatment with Sencor 70 WG reduced dose (0.3 kg ha^{-1}) + Titus 25 WG - (30 g ha^{-1}) + Trend 90 EC (0.1%) applied after potato emergence (Table 5).

It should be expected that the exogenous content of metribuzin in potato leaves caused disturbances in the metabolism of plants, expressing not only morphological, but also physiological changes. Sawicka and Barbaś (2007) proved that the PS II photosystem is the most sensitive indicator of the effects of various stress factors on plants. Kołodziejczyk and Szmigiel (2012) report that the source of nitrogen increase may be the active substance of the applied preparations, but also the increased assimilation surface of chemically protected potato plants. The literature is dominated by the view on the positive impact of plant protection products on the total nitrogen content in potato tubers (Zarzecka, Gugała 2012, Goméz et al. 2017). Herbicides used by Gugała et al. (2015) increased the nitrogen content from 0.07 to 0.22 g kg^{-1} dry mass of tubers and reduced the potassium content by 0.23 to 0.36 g kg^{-1}, compared to the control, without herbicides. More nitrogen in tubers was accumulated by an average early cultivar Irga than medium late Fianna (Table 4). The influence of cultivars on the nitrogen content in potato tubers is also reported by Ereifej et al. (1998), Lachman et al. (2005), Gugała et al. (2015), Płaza et al. (2017), and Gąsiorowska et al. (2018).

Potassium regulates the water management of a plant, activates various enzymatic reactions in a plant, and stimulates the synthesis of proteins, simple sugars, polysaccharides, fats and organic acids (Zarzecka et al. 2013). In our experiment, the potassium content did not depend significantly on the potato protection methods (Table 6).

Wichrowska et al. (2009) showed an increase in the content of this element by 3.5% when using herbicides, compared to treatments with mechanical care. The concentration of potassium in tubers determined by Dobozi et al. (2003) was the highest when Sencor 70 WG and Command 48 EC were used to regulate weed infestation.

Potassium is closely related to the assimilation of nitrogen in plants and can accelerate the transport of NO_3^- from roots to aerial parts of plants, hence its content may be reduced or increased. Zhou et al. (1989) showed that, compared to the control object, the concentration of NO_3^- in cabbage decreases with the use of K^+, while Eppendorfer and Eggum (1994) observed an opposite result in their study on potato plants.

An important mineral element in potato is phosphorus, which is crucial in the ionic and water economy of the plant (Gumul et al. 2011). The research showed a negative effect of mechanical and chemical plant care with herbicides on the phosphorus content in potato tubers (Table 7).

Table 6

Potassium content in the dry mass of tubers depending on the methods of weeding, cultivar and year of cultivation (g kg-1)

Experimental factors		Methods of weed control*								Mean
Cultivar	year	1	2	3	4	5	6	7	8	
Irga	2007	29.86	27.93	26.83	26.50	27.40	27.96	26.40	30.26	27.89
	2008	21.60	23.83	24.16	27.10	25.63	25.86	27.10	26.73	25.25
	2009	22.10	25.33	24.43	26.50	25.73	26.13	26.83	26.90	2.549
	mean	24.52	25.69	25.14	26.70	26.25	26.65	26.77	27.96	26.21
Fianna	2007	30.70	26.33	25.86	25.03	26.03	22.80	24.56	25.13	25.80
	2008	26.00	25.13	25.50	24.90	24.90	22.70	24.40	24.90	24.80
	2009	26.60	2.453	25.70	25.00	25.00	22.83	24.90	25.03	24.94
	mean	27.76	25.33	25.68	24.97	25.31	22.77	24.62	25.02	25.18
Mean for years	2007	30.28	27.13	26.34	25.76	26.71	25.38	25.48	27.69	26.84
	2008	23.80	24.48	24.83	26.00	25.26	24.28	25.75	25.81	25.02
	2009	24.35	24.93	25.06	25.75	25.36	24.48	25.86	25.96	25.21
	mean	26.14	25.51	25.41	25.83	25.78	24.71	25.69	26.49	25.57

$LSD_{0.05}$ cultivars – 0.13, weeding – 0.42, year – 0.19, weeding x cultivar – n.s., cultivar x year – n.s., weeding x year – n.s., * Explanations as in Table 5, n.s. – non-significant differences

Table 7

Phosphorus content (DM) of tubers depending on the methods of weeding, cultivar and year of cultivation (g kg-1)

Experimental factors		Methods of weed control*								Mean
Cultivar	year	1	2	3	4	5	6	7	8	
Irga	2007	3.13	2.76	2.83	2.70	2.96	2.90	2.76	2.56	2.82
	2008	2.96	3.09	2.90	2.38	2.64	2.97	3.04	2.87	2.85
	2009	3.00	2.90	2.80	2.76	2.73	2.96	2.83	2.60	2.82
	mean	3.03	2.91	2.84	2.61	2.77	2.94	2.87	2.67	2.83
Fianna	2007	3.03	2.86	2.80	2.80	2.80	2.76	2.70	2.56	2.78
	2008	2.98	2.66	2.80	2.83	2.96	2.66	2.63	2.60	2.76
	2009	2.73	2.76	2.70	2.80	2.76	2.70	2.63	2.60	2.71
	mean	2.91	2.76	2.76	2.81	2.84	2.70	2.65	2.58	2.75
Mean for years	2007	3.08	2.81	2.81	2.75	2.88	2.83	2.73	2.56	2.80
	2008	2.97	2.87	2.85	2.60	2.80	2.81	2.83	2.73	2.80
	2009	2.86	2.83	2.75	2.78	2.74	2.83	2.73	2.60	2.76
	mean	2.97	2.83	2.80	2.71	2.80	2.82	2.76	2.63	2.79

$LSD_{0.05}$ cultivar – n.s., weeding – 0.13, year – n.s., weeding x cultivar – n.s., cultivar x year – n.s., weeding x year – n.s. * Explanations as in Table 5; n.s. – non-significant differences

The strongest negative effect on the content of this element in tubers appeared in the treatment with the post-emergence application of a mixture of Sencor + Apyros + Atpolan. The application of metribuzin before the emergence of potato at a dose of 1 kg ha^{-1} and after the emergence of the crop (0.5 kg ha^{-1}) reduced the concentration of phosphorus in comparison with mechanical care, but increased the content of this macronutrient compared to the control (Table 7).

Zarzecka et al. (2010) proved that the content of phosphorus and calcium and their uptake depend significantly on the methods of plant care. More phosphorus was accumulated by potato tubers in simplified cultivation compared to traditional, and more calcium accumulated in tubers from traditional cultivation. These authors also stated that the herbicides Barox 460 SL + Fusilade Forte 150 EC + Atpolan 80 EC adjuvant used in potato care contributed to the reduction in the phosphorus content and increase in the calcium content, compared to the control.

The genetic factor determined the content of nitrogen and potassium in tubers. Higher concentrations of these elements are determined in medium-early than medium-late cultivars. Together with genetic variability, environmental variability was also observed. The main reasons for this variability, according to Sawicka et al. (2015), are the quality of seed potatoes, their healthiness, size, storage, but also heterogeneity of the soil environment as well as the degree of infection by diseases, uneven surface area for one plant (due to proximity of diseased plants, lack of emergence), non-uniformity of the impact of meteorological conditions such as temperature, light (wavelength, their intensity and duration), water supply, humidity, rainfall distribution in time. In addition, diversity of the environment in which potato plants grow may cause modification of the internal regulation processes, both within the entire plant and in individual potato stalks. Therefore, there may be variability within the plants, shoots, as well as variability of plants on a plot or in a trench, associated with weather conditions as well as localities. Methodological research by Rymuza et al. (2012), and Sawicka et al. (2015) shows that the determination of physical, chemical or physiological characteristics of plants requires conducting research in at least three years in one locality, or 1-2 years in several localities.

In this experiment, the meteorological conditions had significant influence on the content of nitrogen and potassium. The highest accumulation of these nutrients in tubers was observed in the dry year 2007, and the lowest were accumulated in 2008, a year with a higher amount of precipitation, but lower temperature amplitude. The phosphorus content was not dependent on the weather conditions in the years of the research. Similar results were obtained by Gugała et al. (2015). Weather conditions prevailing during the growing season had significant influence on the concentrations of total nitrogen and potassium, while the phosphorus content was not dependent on this factor.

The content of minerals is believed by many authors (Elfaki, Abbsher 2010, Gumul et al. 2011, Dechassa 2012, Nassar et al. 2012) to be the main determinant of the usefulness of edible tubers intended for direct consumption and for food products. These features depend on the biology of potato, which is strongly influenced by agrometeorological conditions of the growing season, agrotechnical measures, in particular fertilization and protection of potatoes, and storage conditions (Bélanger et al. 2002, Kołodziejczyk, Szmigiel 2005, Blecharczyk et al. 2008, Braun et al. 2011, Ahmed et al. 2015, Goméz et al. 2017, Leonel et al. 2017, Wierzbowska et al. 2018).

CONCLUSIONS

1. As a result of using herbicides, the nitrogen content in potato tubers increased, and there was the tendency towards a lower phosphorus content in potato tubers. The concentration of potassium decreased only after the use of the Sencor 70 WG herbicide applied before the emergence of the crop and in the post-emergence application of the mixture of Sencor 70 WG + Titus 25 WG + Trend 90 EC.

2. High content of nitrogen in tubers was favored by the use of Sencor 70 WG at a reduced dose + Titus 25 WG + Trend 90 EC applied after potato emergence.

3. Lower concentration of nitrogen, phosphorus and potassium characterized an average late cultivar Fianna, as compared to the medium-early cultivar of Irga.

4. Variable weather conditions had a significant effect on the content of nitrogen and potassium but did not affect the concentration of phosphorus in tubers of the tested potato cultivars. The content of nitrogen and potassium in potato tubers was the highest in the wet year 2007, and the lowest – in the dry year 2008.

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