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Content of nitrates in potato tubers depending on the organic matter, soil fertilizer, cultivation simplifications applied and storage

Jarosław Pobereżny[1*], Elżbieta Wszelaczyńska[1], Dorota Wichrowska[1], and Dariusz Jaskulski[2]

Nitrates naturally occur in plant-based food. Nitrates content in consumable plant organs is small and should not raise concern provided that the recommended fertilization and harvest terms of the original plants are observed. The aim was to determine the effect of the application of various organic matter of soil fertilizer and simplifications in growing potato (*Solanum tuberosum* L.) on the content of nitrates in the tubers of mid-early cultivar 'Satina' after harvest and after 6-mo of storage. Introducing cultivation simplification involves limiting mineral fertilization by 50% as well as chemical protection limitation. The soil fertilizer was used: 0.6 (autumn), 0.3 (spring), and 0.3 L ha^{-1} (during the vegetation period). The content of nitrates, was determined with the use of the ion-selective method (multi-purpose computer device CX-721, Elmetron). The lowest amount of nitrates was recorded in the tubers from the plots without the application of organic matter with a 50% rate of mineral fertilization with soil fertilizer (120.5 mg kg^{-1} FW). The use of varied organic matter resulted in a significant increase in the content of nitrates in tubers and the lowest effect on their accumulation was reported for straw. The soil fertilizer used significantly decreased the content of nitrates in tubers by 15% for 100% NPK and 10.4% for 50% NPK. After 6-mo storage, irrespective of the experiment factors, the content of nitrates decreased in the fertilization experiment by 26% and in the experiment with a limited protection – by 19.9%.

Key words: Chemical protection, mineral fertilization, nitrates, soil fertilizer, *Solanum tuberosum*, storage.

INTRODUCTION

In agriculture, for the last dozen or so years dynamic changes have occurred. Besides the basic tasks, such as the food and animal feed production, the importance of environmental protection has been much greater and greater (Alfaro et al., 2008). What is also essential is an increased awareness of the consumer who is, to a large extent, interested in purchasing 'healthy' food, free from harmful compounds. The idea of the environmental protection and the consumer as such makes us search for new possibilities by introducing cultivation simplifications or the application of various kinds of biostimulants, resistance stimulants, bacterial vaccines, algae extracts, effective microorganisms agents or soil fertilizers (Yildirim et al., 2002; Emitazi et al., 2004; Vernieri et al., 2005; Trawczyński, 2007; Trawczyński and Bogdanowicz, 2007). Similarly, in the developing system of integrated potato cultivation, due to a decreased amount of FYM (the manure) which is a basic organic fertilizer, catch crops and straw or in the processing of organic waste (salmon sludge) can offer an alternative source of biomass (Teuber et al., 2007). Nitrogen in potato (*Solanum tuberosum* L.) tubers can be present in a form of desired amino acids, proteins or harmful nitrates and glycoalkaloids (Hamouz et al., 2005). Nitrates are not harmful; however, when affected by digestive enzymes, they get transformed into nitrites which, in turn, get changed into N-nitro compounds. They cause the oxidation of hemoglobin to methemoglobin. The problem of their accumulation in vegetables is especially important since the share of nitrates from vegetables in the daily human rations accounts for 70% to 90% (Zgórska and Sowa-Niedziałkowska, 2005; Jarych-Szyszka, 2006; Bottex et al., 2008; Ierna, 2009; Rytel, 2010). The interest in those compounds comes from the fact that the method of their accumulation (in the outer layer of vegetables) when exposed to a high environmental pollution can exceed the acceptable level (Ministry of Health, 2003).

Joint FAO/WHO Expert Committee on Food Additives (JECFA) (JECFA, 2002) fixed daily intake of an adult of nitrates on the level of 0-3.7 mg and nitrites 0-0.7 mg kg^{-1} body mass. From the fixed values it results that the acceptable daily intake (ADI) by an adult of 70 kg cannot exceed 260 mg of nitrates and 49 mg nitrites. However, the dose of nitrates exceeding 8-11 mg kg^{-1} body weight d^{-1} is lethal (Burt et al., 1993).

[1]University of Technology and Life Sciences in Bydgoszcz, Department of Microbiology and Food Technology, Kordeckiego 20, 85-225 Bydgoszcz, Poland.
[*]Corresponding author (poberezny@utp.edu.pl).
[2]University of Technology and Life Sciences in Bydgoszcz, Department of Plant Production and Experimental, Kordeckiego 20, 85-225 Bydgoszcz, Poland.
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Considering the order of constant chemical monitoring of foodstuffs contamination, dynamic development of ecology in cultivation as well as still high consumption of potato, research has been launched to determine the effect of the application of various organic matter, soil fertilizer, and simplifications in its cultivation on the content of nitrates in the tubers of mid-early 'Satina' right after harvest and after 6-mo storage.

MATERIALS AND METHODS

Over 2009-2011 in the Kuyavia-Pomerania region, Experimental Station the Faculty of Agriculture and Biotechnology (53°13' N, 17°51' E; 100 m a.s.l.) located in north central Poland there were performed field experiments set up in Luvisol, formed from glacial till, qualified as good rye complex. The two experiments were set up as three-factor in split-plot, in three replicates. The research material involved the mid-early potato (*Solanum tuberosum* L.) 'Satina N'. Cereals constituted the forecrop. Potatoes were mechanically planted at 0.75 × 0.35 m row spacing. Single plot size was 35 m^2.

Experiment I (2009-2010, 2010-2011)
Factor (A): application of varied organic matter (FYM, straw, stubble intercrop without additional matter); Factor (B): NPK fertilization (100% and 50%); Factor (C): fertilization with the soil fertilizer (fertilization, lack).

Experiment II (2009-2010, 2010-2011)
Factor (A): chemical protection (full protection, without herbicides, without fungicides, without insecticides); Factor (B): organic matter application (FYM, straw, stubble intercrop, without additional matter); Factor (C): fertilization with soil fertilizer (fertilization, lack).

Mineral fertilizers were used in spring before potato planting at the following rates: 100 kg N ha^{-1} as ammonium nitrate (34%) (Group Azoty Nitrogen Establishments Pulawy SA, Poland, PULAN saletra amonowa [NH_4NO_3]); 100 kg P_2O_5 ha^{-1} triple superphosphate (46%), (Group Azoty Chemical Establishments Police SA, Poland, superfosfat potrójny [$Ca(H_2PO_4)_2$]); 150 kg K_2O ha^{-1} potassium sulfate (50%), (Establishments Trading Commodities Siarkopol Sp. z o.o. Tarnobrzeg, Poland, siarczan potasu [K_2SO_4]). The soil fertilizer (UGmax) was used at three rates: in autumn prior to pre-winter plough on the organic matter at 0.6 L ha^{-1}, in spring prior to tuber planting during tillage at 0.3 L ha^{-1}, foliar application during the vegetation, with the potato plants 15-20 cm high at 0.3 L ha^{-1}. During the cultivation the following potato protection agents were applied; fungicides: cymoksanil and mancozeb (2-cyano-N-[(ethylamino)carbonyl]-2(methoxyimino) acetamide and zinc complex of ethylene-bis-dithiocarbamate manganese, Helm AG, Germany, Helm-Cymi 72.5 WP; 2 kg ha^{-1}), mefenoxan and mancozeb (methyl *N*-(methoxyacetyl)-*N*-2,6-xylyl-D-alaninate and zinc complex of ethylene-bis-dithiocarbamate manganese, Syngenta Crop Protection AG, Switzerland - Ridomil Gold MZ 67.8 WG; 2 L ha^{-1}), insecticide: chlorpyrifos and cypermethrin (*O*,*O*-diethyl *O*-3,5,6-trichloro-2-pyridyl phosphorothioate and (*RS*)-α-cyano-3-phenoxybenzyl (1*RS*,3*RS*;1*RS*,3*SR*)-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarbo xylate, respectively, Agriphar S.A., Belgium - Nurelle D 550 EC; 0.6 L ha^{-1}) as well as herbicide linuron (3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea, Agan Chemical Manufactures Ltd., Israel, Afalon 50WP; 2 L ha^{-1}).

UGmax is a compost extract which includes, next to a set of microorganisms, includes the medium which facilitates their activation. Those microorganisms are claimed to show some properties of transforming, composting and mummifying natural and organic fertilizers to produce humus. That agent enhances the soil structure, which facilitates water retention and alleviates drought effects. It also limits bayous and floodings, increases plant resistance and health status, helps the development of the root system and fixing free N.

The composition of Ugmax includes bacteria of lactic acid, photosynthetic bacteria, Azotobakter Pseudomonas, Actinobacteria. Micro- and macroelements: 3500 mg K L^{-1}, 1200 mg N L^{-1}, 100 mg S L^{-1}, 500 mg P L^{-1}, 200 mg Na L^{-1}, 100 mg Mg L^{-1}, 20 mg Zn L^{-1}, and 0.3 mg Mn L^{-1} (Trawczyński, 2007).

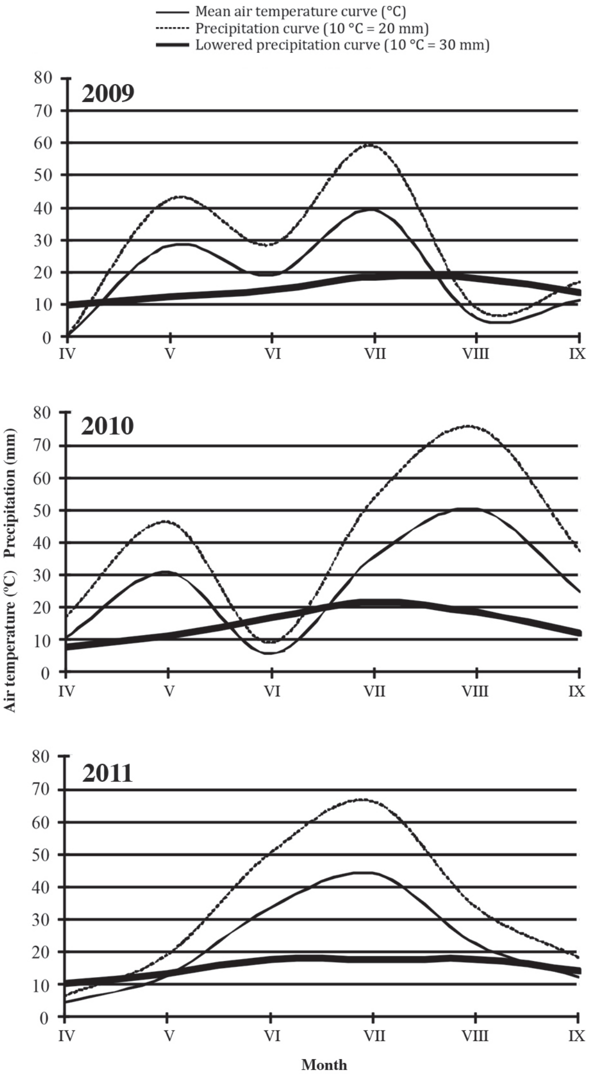
The field experiment was carried out in light soil with a slightly acid reaction, mean richness in available P and K forms and very low Mg richness (Table 1).

The climate conditions pattern during vegetation period was defined with the use of the mean air temperature curve (°C), rainfall curve (10 °C = 20 mm), and a lowered rainfall curve (10 °C = 30 mm) according to Gregorczyk et al. (2005). The values falling within the area defined by the rainfall curve below the temperature curve stand for the period of drought. The 2009 and 2011 (Figure 1) seasons demonstrated drought periods in the first and in the final stage of potato vegetation, while the conditions unfavorable to the potato growth and development in the 2010 vegetation season occurred during tuberization.

Harvest was made at full physiological potato maturity. From each plot samples were taken for storage (10 kg). The process of storage was conducted in chambers with controlled conditions in the Institute of Food Technology of the University Technology and Life Sciences in

Table 1. Chemical content of soil before field experiments in 2009-2011.

Parameters	Value	Categories
pH H_2O	5.1-6.7	Light acidic
pH KCl	4.7-6.1	
Organic C, g kg^{-1}	7.55-7.80	-
Total N, g kg^{-1}	0.69-0.75	Low richness
Available P, mg kg^{-1}	190.0-210.0	High richness
Available K, mg kg^{-1}	95.0-150.0	Medium richness
Available Mg, mg kg^{-1}	< 20.0	Very low richness



Area determined by the precipitation curve below the temperature curve = period of drought.
Area determined by the lowered precipitation curve below the temperature curve = period of semi-drought.

Figure 1. Meteorological conditions in 2009-2011, according to Gregorczyk et al. (2005).

Bydgoszcz. In the period of 6-mo of storage, a constant temperature and relative air humidity were maintained, being adjusted to the potato tubers use method. Potato tubers were stored at 4 °C and 95% RH.

The content of nitrates was determined directly after harvest and after 6-mo storage, with the use of the ion-selective method (Kunsch et al., 1981) with the application of the multi-purpose computer device CX-721 (Elmetron, Zabrze, Mikulczyce, Poland). The apparatus was equipped with a nitrate electrode, double junction reference electrode (fill outer chamber with 0.02 M $(NH_4)_2SO_4$ solution; Merck, Germany) and specific ion meter or a pH/millivolt (mV) meter with readability to 0.1 mV.

Laboratory analysis procedure

The plant material was purified and foreign substances were eliminated, including soil and dust particles, and foliar spray residues that may influence analytical results. Plant tissue samples were reduced to 0.5-1.0 mm particle size is to ensure homogeneity and to facilitate organic matter destruction. In the analytical research at each stage, deionized water was used.

Nitrates were extracted by $KAl(SO_4)_2$ (Merck, Darmstadt, Germany) solution and determined potentiometrically by ion-selective electrode. The method has been accredited by the Polish Accreditation Body. The determination limit was 30 mg kg^{-1} and measurement error up to 15% (k = 2, norm.) depending on the sample matrix. Dried plant tissue (2 g) was ground to pass through a 20-mesh sieve; 50 mL 1% of $KAl(SO_4)_2$ extracting solution was added and shaken for 1 h. Next 10 mL $Al_2(SO_4)_3$ was added (Merck) and shaken immediately before the test. Standards are made in the 0.025 M $Al_2(SO_4)_3$ background solution. It is important that the concentration of the samples be within the range of the standards.

In this work food consumption data from the Board of Statistics were used in the calculation of average intake for the whole population. The amounts of potato tubers consumed were reduced, taking into account the effect of peeling, cleaning and removing of non-edible parts. Nitrate concentrations of the commodities were corrected for cooking loss.

The 3-yr research results were statistically verified applying ANOVA method. The significance of differences (LSD: lowest significance difference) was evaluated using the Tukey multiple confidence intervals for the significance level of $\alpha = 0.05$. The ANOVA of data was computed using the Statistica (SAS Institute, Cary, North Carolina, USA) computer program.

RESULTS AND DISCUSSION

The content of nitrates is especially affected by fertilization with mineral N and cultivar (Lin et al., 2004; Zgórska and Sowa-Niedziałkowska, 2005; Jarych-Szyszka, 2006; Tietze et al., 2007; Murawa, 2008; Ierna, 2009; Marks, 2009; Rytel, 2010; Pobereżny et al., 2012). In the present research the content of nitrates in 'Satina' potato tubers, irrespective of the experiment factors, was mean 143.9 for Experiment I (Table 2) and mean 140.6 mg kg^{-1} FW for Experiment II (Table 3). The standard deviations indicate a small variation of nitrate in researches years. Lachman and Hamouz (2005) as well as Hamouz et al. (2005) report on the content of nitrates ranged from 70.2 for 'Agria' to 199.2 mg kg^{-1} FW for 'Impala'. Murawa et al. (2008) as well as Tietze et al. (2007) report on the content of nitrates in potato (mean for many samples) ranged from 167.1 to 259.6 mg kg^{-1} FW do not list the cultivars, however. Zgórska and Sowa-Niedziałkowska (2005), investigating 15 cultivars as well as Marks (2009) seven cultivars, recorded the content of nitrates in tubers from 71.0 to 270.0 mg kg^{-1} FW as well as from 77.0 to 102.0 mg kg^{-1} FW, respectively. In the studies performed by Wadas et al. (2012), the range of the content of that component for three cultivars was from 72.3 to 94.7 mg kg^{-1} FW. Wierzbicka et al. (2008) determined the content of NO_3^- as 132.0 for 'Denar' and 237.0 mg kg^{-1} FW for 'Karatom'. Different results were recorded by Rutkowska (2005), who did not find significant differences in the accumulation of nitrates across the three potato cultivars investigated ('Bryza', 'Sokół', 'Irys').

In the present research potato tubers collected from traditional farming (FYM + mineral fertilization) (Table 2) accumulated most nitrates (156.9 mg kg^{-1} FW), which coincides with the results reported by Rutkowska (2005), Tamme et al. (2006) who also recorded a higher content of nitrates in the tubers grown in traditional farming. It is the result of the content of N in the fertilizers that had been used. As an addition, manure causes the improvement of the content of humus in soil. It causes improvement of the amount and availability of food ingredients for plants. The form of giving N to plants is also really important. Considering the currently binding norms, investigating the content of nitrates in potatoes commercially available from traditional farming, Murawa et al. (2008) defined potato as a vegetable posing a high threat for the consumer. They report on the norm of the content of nitrates being exceeded in the first year in 30% of the samples and in the second year even in 72% samples. Lachman and Hamouz (2005) and Hamouz et al. (2005), however, did not show a significant effect of the potato growing method (organic and traditional) on the content of nitrates in the tubers of eight cultivars: 'Impala', 'Karin', 'Agria', 'Nimfa', 'Korela', 'Rosella Sante', and 'Ornella'. One shall note, however, that they observed a tendency for a higher content of nitrates in traditional farming (153.9 mg kg^{-1}) as compared with organic farming (136.9 mg kg^{-1}). Such a result was due to the traditional farming involving higher N fertilization rates. Similar results were recorded by Zarzyńska and Goliszewski (2005) and Pussemier et al. (2006), which coincides with the present results since the application of 100% N fertilization, namely 100 kg N ha^{-1}, resulted in a significant increase in the content of nitrates by 4.9%, as compared with the 50% N rate (Table 2).

Jarych-Szyszka (2006), increasing the N rate from 40 to 120 kg N ha^{-1}, reported an increase in the content of nitrates in the tubers of two cultivars ('Bard' and 'Lord') by an average of 15%. Jabłoński (2006), increasing the N rate from 50 to 150 kg, recorded an increase in the content of nitrates in the tubers of 'Wiking' and 'Zeus' as much as from 95% to 153%. Janowiak et al. (2009), on the other hand, determined that increase as accounting for as much as 72% and they have determined 120 kg N as a safe N fertilization rate for table potato. According to Wierzbicka et al. (2008), the rate should range from 50 to 90 kg N ha and it depends on the cultivar earliness. Wadas et al. (2012) observed that the fertilization with multicomponent

Table 2. Nitrates content in potato tubers depending on factors research (organic and mineral fertilization) after harvest. Mean from 2009-2011 seasons (mg kg^{-1} FW).

Experimental factors		Mineral fertilization (B)		
Organic matter (A)	Soil fertilizer (C)	100%	50%	Mean value
Control	Without soil fertilizer	136.0 ± 1.5	127.9 ± 0.3	132.0 ± 0.9
	Soil fertilizer	121.3 ± 15.8	120.5 ± 15.6	120.9 ± 15.7
	Mean	128.7 ± 7.4	124.2 ± 3.7	126.4 ± 5.6
Stubble intercrop	Without soil fertilizer	160.9 ± 10.1	142.0 ± 4.5	151.5 ± 7.3
	Soil fertilizer	151.8 ± 8.1	148.2 ± 8.6	150.0 ± 8.4
	Mean	156.4 ± 4.6	145.1 ± 3.1	150.7 ± 8.7
Straw	Without soil fertilizer	154.6 ± 7.7	144.9 ± 9.0	149.8 ± 8.4
	Soil fertilizer	137.3 ± 7.1	129.5 ± 7.2	133.4 ± 7.1
	Mean	146.0 ± 8.7	137.2 ± 7.7	141.6 ± 8.2
Manure	Without soil fertilizer	186.3 ± 6.4	167.4 ± 15.3	176.9 ± 10.9
	Soil fertilizer	144.5 ± 3.3	129.5 ± 3.8	137.0 ± 3.6
	Mean	165.4 ± 9.2	148.5 ± 9.0	156.9 ± 10.2
Mean value	Without soil fertilizer	159.5 ± 11.8	145.6 ± 7.4	152.5 ± 9.6
	Soil fertilizer	138.7 ± 10.4	131.9 ± 6.9	135.3 ± 8.6
	Mean	149.1 ± 16.1	138.7 ± 12.0	143.9 ± 13.9

Values are means ± standard deviation (n = 3), ns: nonsignificant.
Tukey's test (LSD, P ≤ 0.05), factors: A: 2.3; B: 2.7; C: 5.0; A/B: 4.3; B/A: 5.3; C/A: 10.1; A/C: 7.4; C/B: ns; B/C: ns.

Table 3. Nitrates content in potato tubers depending on factors research (organic fertilization and chemical protection) after harvest. Mean from 2009-2011 seasons (mg kg^{-1} FW).

Experimental factors		Organic matter (B)				
Potato chemical protection (A)	Soil fertilizer (C)	Control	Stubble intercrop	Straw	Manure	Mean value
Complete chemical protection against pests	Without soil fertilizer	136.0 ± 1.5	160.9 ± 10.1	154.6 ± 7.7	186.3 ± 6.4	159.5 ± 6.4
	Soil fertilizer	121.3 ± 15.8	151.8 ± 8.1	137.3 ± 7.1	144.5 ± 3.3	138.7 ± 8.6
	Mean	128.7 ± 13.6	156.4 ± 7.4	146.0 ± 4.6	165.4 ± 8.7	149.1 ± 10.4
Without herbicides	Without soil fertilizer	162.0 ± 0.7	137.2 ± 22.7	169.8 ± 0.8	133.8 ± 7.4	150.7 ± 7.9
	Soil fertilizer	150.4 ± 5.9	127.2 ± 28.1	120.6 ± 26.8	106.6 ± 0.6	126.2 ± 15.4
	Mean	156.2 ± 13.5	132.2 ± 24.6	145.2 ± 13.6	120.2 ± 12.3	138.5 ± 24.6
Without fungicides	Without soil fertilizer	124.2 ± 16.3	123.8 ± 17.0	141.1 ± 5.6	153.5 ± 11.3	137.9 ± 12.6
	Soil fertilizer	118.6 ± 23.2	124.3 ± 18.4	127.4 ± 21.9	126.7 ± 9.0	124.3 ± 18.1
	Mean	121.4 ± 6.9	128.6 ± 4.3	134.3 ± 6.9	140.1 ± 12.8	131.1 ± 13.4
Without insecticides	Without soil fertilizer	149.5 ± 5.4	142.9 ± 1.3	138.3 ± 9.8	152.7 ± 3.7	145.9 ± 5.1
	Soil fertilizer	150.0 ± 11.0	128.9 ± 4.9	137.8 ± 10.3	149.7 ± 4.0	141.6 ± 7.6
	Mean	149.8 ± 6.8	135.9 ± 7.0	138.1 ± 11.5	151.2 ± 2.1	143.7 ± 9.3
Mean value	Without soil fertilizer	142.9 ± 5.7	143.5 ± 6.1	151.0 ± 8.2	156.6 ± 6.5	148.5 ± 15.4
	Soil fertilizer	135.1 ± 15.9	133.1 ± 8.5	130.8 ± 13.5	131.9 ± 10.7	132.7 ± 14.8
	Mean	139.0 ± 12.9	138.3 ± 4.4	140.9 ± 8.3	144.2 ± 10.6	140.6 ± 17.5

Tukey's test (LSD, P ≤ 0.05), factors: A: ns; B: ns; C: 3.5; B/A: 17.6; A/B: 24.4; C/A: 6.9; A/C: 19.8; C/B: 6.9; B/C: 9.9.
Values are means ± standard deviation (n = 3).
ns: nonsignificant.

N fertilizers increases the content of nitrates in tubers. Lin et al. (2004) and Pobereżny et al. (2012), on the other hand, report on the content being affected by not only the selection of the fertilizer but also the method of its application. Zarzyńska and Wroniak (2007) claim that the content of nitrates depends significantly not on the simplifications introduced in potato growing but on the soil where such simplifications are applied. More nitrates were accumulated by the tubers of potato grown in the simplified system on heavier soils.

Potato should be cultivated on FYM which enhances the physicochemical properties of soil. Such fertilization is also attributed with a big role in the development of the chemical composition of tubers (Haase et al., 2007; Nyiraneza and Snapp, 2007). In the present research each of the natural fertilizers applied significantly increased the content of nitrates, as compared with the control. Using the straw does not reduce nitrates content in a relative to control object, but only the nitrates content in tubers is lower in a relative to manure and mineral fertilization. The biggest influence on the nitrates content between factors studding had manure and mineral fertilization, and the lowest- fertilization with straw. Using the straw does not reduce the nitrates content relative to control object, but only the nitrates content in tubers is lower relative to manure and mineral fertilization. The biggest influence on the nitrates content between factors studding had manure and mineral fertilization, and the lowest fertilization with straw. The content of nitrates was most increased by FYM, followed by pea and least by straw, applied with 100% NPK fertilization (Table 2). As compared with the control, the increase accounted for 37% for FYM, 18.3% for pea and 13.7% for straw. When limiting mineral fertilization to 50%, the results were slightly different. The increase, against the control, accounted for 30.9% for FYM, 13.3% for straw and 11.0 % for pea. One shall also note that the application of the soil fertilizer, limited the increase in the content of that unwanted component considerably. Irrespective of the natural fertilizer, the decrease in the content of nitrates, as compared with the no-fertilizer-treatment, was 15% for 100% NPK and 10.4% for 50% NPK. Besides, there was recorded a significant interaction of the factors studied. The best results were recorded for the tubers from the plots without organic matter with a 50% rate of mineral fertilization with soil fertilizer (120.5 mg kg^{-1} FW). However, in the combination straw+soil fertilizer and FYM+soil fertilizer with the NPK rate decreased by half there was recorded a slightly higher content of nitrates (129.5 mg kg^{-1} FW). Trawczyński and Bogdanowicz (2007) introducing simplifications in mineral fertilization in the conditions of fertilization with the soil fertilizer on the straw recorded a similar content of nitrates in tubers as for the application of straw only.

Potatoes allocated to foodstuffs industry most often come from traditional farming where, besides high mineral fertilization rates, intensive protection is used, which can result in an increase in the content of antifeedant compounds: nitrates, above the amount considered safe (Murawa et al., 2008; Ierna, 2009; Rytel, 2010). In the present research, irrespective of the organic matter applied, the highest amount of nitrates was recorded in the tubers from the plots with a complete protection; on average 149.1 mg kg^{-1} FW (Table 3), which can be due to the highest amount of chemical agents used on those plots. Interestingly the use of simplifications in the protection of plantation and a varied kind of organic matter was significant for the content of nitrates only in respective combinations, which confirms a high scatter of standard deviations. Most nitrates was recorded in the tubers grown on FYM with a complete protection with 165.4 mg kg^{-1} FW and the least on FYM without herbicides 121.4 mg kg^{-1} FW. One shall thus assume that the content of nitrates is mostly affected by FYM, which was show with significant differences in Experiment II and described above. Irrespective of other factors, a significantly positive effect on the content of nitrates in tubers was reported for soil fertilizer; it decreased their content by an average of 11.9%. Its best effect was observed for the simplification without herbicides: the decrease in the content of nitrates by 19.4%, and the lowest, without insecticides, decrease in the content of nitrates only by 3%. It is very justifiable since the soil fertilizer, by enhancing the soil conditions, can decrease weed infestation and hence improve the tuber quality. There was also recorded a very positive effect of the soil fertilizer with a complete protection of the crop; a decrease in the content of nitrates by 15%. It is confirmed by the results reported by Zarzyńska and Goliszewski (2005). The results recorded by the authors on the chemical composition of the tubers indeed do not fully confirm the reports on a much better quality of potatoes from simplified plantations with the use of the agents based on microorganisms; however, a much lower content of nitrates speaks for the benefit of those plantations.

In the present research the content of nitrates in potatoes in none of the samples exceeded the admissible level of 200 mg NO_3^- kg^{-1} (Ministry of Health, 2003), which coincides with the results reported by Jarych-Szyszka (2006) and Marks (2009). However, Zarzyńska and Goliszewski (2005) report three cultivars out of five exceeding the predefined threshold of the content of nitrates in integrated farming on heavy soils treated with the rate of 80 kg N ha^{-1}. According to (Jarych-Szyszka, 2006; Pęksa et al., 2006; Rytel, 2010), the highest concentration of nitrates is found in the peel or right under it in the tuber. Researching the content of those compounds, it seems important that during tuber peeling and washing the amount of those compounds gets much lower. According to Jarych-Szyszka (2006) the processes result in a decrease in the content from 20% to 30%. Gołaszewska and Zalewski (2001) report on the decrease in the content of nitrates to account for 36% to 42%, and as reported by Grudzińska (2005) and Zgórska and Grudzińska (2004) it accounted for as much as from 40% to 67%. Rytel (2010) noted that the content of nitrates in tubers also affects the peeling method.

According to many authors, inadequate storage conditions (increased temperature, no oxygen access) increase the content of nitrates in vegetables (Amr and Hadidi, 2001; Zgórska and Sowa-Niedziałkowska, 2005; Tamme et al., 2006; Gajewska et al., 2009; Ierna, 2009; Ciećko et al., 2010). In the present research the mean content of nitrates after 6-mo storage, irrespective of the experiment factors, decreased in the fertilizer experiment by 26% and in the experiment with a limited chemical protection by 19.9% (Tables 4 and 5), which coincides with the results by Janowiak et al. (2009), Wichrowska (2007) and Pobereżny et al. (2012) where the content of nitrates after 6-mo storage decreased by 10.6%, 23%, and 37.5%, respectively. Whereas Gajewska et al. (2009) as well as Ciećko et al. (2010) after a long-term storage demonstrated an increase in their content. Unlike Zgórska and Sowa-Niedziałkowska (2005) who storing tubers of 15 cultivars showed that during storage at 4 ºC there are little changes in the content of nitrates. After 3-mo the content of those compounds, as compared with the content after harvest, decreased by 6.7% and then after 8-mo storage by 6.1%. Only the storage at a higher temperature (+8 ºC) resulted in a greater increase in the content of nitrates by 20%. However Tamme et al. (2006) and Marks (2009) and reports on the effect of the length of the storage period on the content of nitrates being nonsignificant. One shall

Table 4. Nitrates content in potato tubers depending on factors research (organic and mineral fertilization) after storage. Mean from 2009-2011 seasons (mg kg^{-1} FW).

Experimental factors		Mineral fertilization (B)		
Organic matter (A)	Soil fertilizer (C)	100%	50%	Mean value
Control	Without soil fertilizer	105.4 ± 5.9	100.5 ± 2.6	102.9 ± 4.2
	Soil fertilizer	103.8 ± 2.1	99.0 ± 1.7	101.4 ± 1.9
	Mean	104.6 ± 2.8	99.7 ± 3.4	102.2 ± 5.8
Stubble intercrop	Without soil fertilizer	128.5 ± 4.1	112.3 ± 1.8	120.4 ± 3.0
	Soil fertilizer	118.3 ± 4.2	116.5 ± 1.6	117.4 ± 2.9
	Mean	123.4 ± 5.1	114.4 ± 2.9	118.9 ± 5.1
Straw	Without soil fertilizer	118.3 ± 4.2	114.7 ± 3.7	116.5 ± 4.0
	Soil fertilizer	117.6 ± 3.1	111.8 ± 1.2	114.7 ± 1.9
	Mean	118.0 ± 4.4	113.2 ± 1.7	115.6 ± 5.2
Manure	Without soil fertilizer	139.1 ± 9.3	124.2 ± 3.9	131.6 ± 6.6
	Soil fertilizer	113.2 ± 5.2	104.1 ± 2.1	108.6 ± 1.7
	Mean	126.1 ± 13.0	114.1 ± 10.1	120.1 ± 11.5
Mean value	Without soil fertilizer	122.8 ± 5.6	112.9 ± 2.8	117.9 ± 4.2
	Soil fertilizer	113.2 ± 4.8	107.8 ± 9.6	110.5 ± 7.3
	Mean	118.0 ± 9.5	110.4 ± 7.0	114.2 ± 8.1

Tukey's test (LSD, P ≤ 0.05); factors: A: 3.0; B: 4.2; C: 3.7; A/B: ns; B/A: ns; A/C: 5.8; C/A: 7.3; B/C: ns; C/B: ns.
Values are means ± standard deviation (n = 3), ns: nonsignificant.

Table 5. Nitrates content in potato tubers depending on factors research (organic fertilization and chemical protection) after storage. Mean from 2009-2011 seasons (mg kg^{-1} FW).

Experimental factors		Organic matter (B)				
Potato chemical protection (A)	Soil fertilizer (C)	Control	Stubble intercrop	Straw	Manure	Mean value
Complete chemical protection against pests	Without soil fertilizer	105.4 ± 5.9	128.5 ± 4.1	118.3 ± 4.2	139.1 ± 9.3	122.8 ± 1.7
	Soil fertilizer	103.8 ± 2.1	118.3 ± 4.2	117.6 ± 3,1	113.2 ± 1.2	113.1 ± 1.0
	Mean	104.6 ± 8.3	123.4 ± 0.8	118.0 ± 5.1	126.1 ± 13.5	118.1 ± 4.8
Without herbicides	Without soil fertilizer	128.6 ± 4.2	113.6 ± 1.6	108.2 ± 2.3	133.3 ± 5.0	120.9 ± 1.3
	Soil fertilizer	119.2 ± 9.1	107.3 ± 2.8	102.8 ± 2.1	122.2 ± 4.6	112.8 ± 1.1
	Mean	123.9 ± 9.2	110.4 ± 4.7	105.5 ± 3.2	127.7 ± 4.1	116.9 ± 4.1
Without fungicides	Without soil fertilizer	108.4 ± 8.6	108.5 ± 4.1	110.7 ± 2.5	129.3 ± 4.0	114.2 ± 3.5
	Soil fertilizer	120.5 ± 11.2	121.0 ± 6.6	116.2 ± 3.8	126.8 ± 1.2	121.1 ± 5.1
	Mean	114.4 ± 6.0	114.7 ± 6.3	113.5 ± 2.8	128.0 ± 3.5	117.7 ± 4.4
Without insecticides	Without soil fertilizer	119.7 ± 2.3	115.9 ± 2.5	113.4 ± 3.3	126.6 ± 3.7	118.9 ± 3.1
	Soil fertilizer	120.6 ± 7.1	103.4 ± 3.1	112.1 ± 3.4	123.4 ± 1.6	114.9 ± 6.5
	Mean	120.1 ± 6.1	109.6 ± 6.3	112.7 ± 8.7	125.0 ± 1.6	116.9 ± 7.5
Mean value	Without soil fertilizer	115.5 ± 7.6	116.6 ± 3.7	112.6 ± 8.3	132.1 ± 7.6	119.2 ± 6.1
	Soil fertilizer	116.0 ± 3.7	112.5 ± 2.5	112.2 ± 4.6	121.4 ± 8.1	115.5 ± 9.3
	Mean	115.8 ± 5.5	114.5 ± 3.8	112.4 ± 4.5	126.7 ± 5.3	117.3 ± 6.9

Tukey's test (LSD, P ≤ 0.05); factors: A: ns; B: 4.8; C: 2.4; B/A: 9.7; A/B: 11.1; C/A: 4.7; A/C: 7.8; C/B: 4.7; B/C: 5.8
Values are means ± standard deviation (n = 3).
ns: nonsignificant.

Table 6. Daily human consumption of nitrates per 300 g potato tubers[1] depending on chemical protection organic fertilization and soil fertilizer. Mean from 2009-2011 seasons (mg d^{-1})[2].

Experimental factors		Organic matter							
		Control		Stubble intercrop		Straw		Manure	
Potato chemical protection	Use soil fertilizer (C)	1[1]	2[1]	1	2	1	2	1	2
Complete chemical protection against pests	Without soil fertilizer	40.8	31.6	48.3	38.6	46.4	35.5	55.9	41.7
	Soil fertilizer	36.4	31.1	45.5	35.5	41.2	35.3	43.4	34.0
Without herbicides	Without soil fertilizer	48.6	38.6	41.2	34.1	50.9	32.5	40.1	40.0
	Soil fertilizer	45.1	35.8	38.2	32.2	36.2	30.8	32.0	36.7
Without fungicides	Without soil fertilizer	37.3	32.5	39.8	32.6	42.3	33.2	46.1	38.8
	Soil fertilizer	35.6	36.2	37.3	36.3	38.2	34.9	38.0	38.0
Without insecticides	Without soil fertilizer	44.9	35.9	42.9	34.8	41.5	34.0	45.8	38.0
	Soil fertilizer	45.0	36.2	38.7	31.0	41.3	33.6	44.9	37.0

[1]Mean consumption of potato tubers is 109 kg yr^{-1} per person in Poland.
[2]Acceptable daily intake (ADI) of nitrates 200 mg d^{-1} (Ministry of Health, 2003).

Table 7. Daily human consumption of nitrates per 300 g potato tubers[1] depending on soil fertilizer, organic and mineral fertilization. Mean from 2009-2011 seasons (mg d^{-1})[2].

Experimental factors		Mineral fertilization			
		100%		50%	
Organic matter	Soil fertilizer	1	2[1]	1	2
Control	Without soil fertilizer	40.8	31.6	38.4	30.2
	Soil fertilizer	36.4	31.1	36.2	29.7
Stubble intercrop	Without soil fertilizer	48.3	38.6	42.6	33.7
	Soil fertilizer	45.5	35.5	44.5	35.0
Straw	Without soil fertilizer	46.4	35.5	43.5	34.4
	Soil fertilizer	41.2	35.3	38.9	33.5
Manure	Without soil fertilizer	55.9	41.7	50.2	37.3
	Soil fertilizer	43.4	34.0	38.9	31.2

[1]Mean consumption of potato tubers is 109 kg yr^{-1} per person in Poland.
[2]Acceptable daily intake (ADI) of nitrates 200 mg d^{-1} (Ministry of Health, 2003).

also note that the lowest content of nitrates after harvest was recorded for the tubers, which contained their lowest amount after harvest. Similar results were also recorded by Chung et al. (2004).

The consumption of 300 g of the potatoes studied does not result in exceeding the acceptable daily intake for nitrates and so it does not trigger the slightest concern about the consumer health (Tables 6 and 7). The mean total intake of nitrate per person in Europe ranges between 50 and 140 mg per day and in the USA about 40 to 100 mg d^{-1} (Ysart et al. 1999; Mensinga et al., 2003). The application of natural fertilizers and increased mineral fertilization increases the consumption of nitrates, while the simplifications in the protection of the plantation differentiated the daily amount of nitrates inconsiderably. We provide the body with the lowest amount of nitrates by consuming 300 g potatoes without the use of fungicides and herbicides: 39.3 and 41.6 mg per ration, respectively. The soil fertilizer applied during the vegetation period decreased the daily amount of nitrates introduced with a ration of potatoes by 12.1% after harvest and by 1.7% after storage. One shall also note that, irrespective of the experiment factors, a long-term storage decreased the daily amount of nitrates by as much as 19.9%. Similar results were also recorded by Chung et al. (2004).

CONCLUSIONS

The application of a varied organic matter significantly increased the content of nitrates and it was straw which demonstrated the lowest effect on their accumulation. Introducing simplifications in the plantation protection did not differentiate the contents of nitrates in tubers. The soil fertilizer applied decreased the content of nitrates in potato tubers irrespective of the farming system. After 6-mo storage, irrespective of the experiment factors, the content of nitrates decreased in the fertilizer experiment by 26% and in the experiment with a limited protection by 20%. The lowest content of nitrates after storage was recorded for the tubers which contained their lowest amount after harvest and its admissible amount was not exceeded. The daily amount of nitrates with the ration of 300 g potatoes, as compared with the norm, was at a very low level and the use of the soil fertilizer and storage decreased it additionally.

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