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Correlation between the levels of nitrates and nitrites and the contents of iron, copper and manganese in potato tubers

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Abstract

In tubers of 16 cultivars of consumable potatoes, cultivated in the Experimental Station of Varieties Appraisal at Węgrzce near Cracow in the years 1991–1992, the contents of iron, copper and manganese as well as levels of nitrates and nitrites, were determined. Statistical analysis of results showed a significant effect of cultivar and the year of cultivation on the contents of studied components. A significant negative correlation between the levels of nitrites and the content of copper in the tested tuber as well as a positive correlation between the levels of iron and copper were found.

1. Introduction

Among the factors influencing physiological-and-biochemical processes connected with nitrogen transformation in plants, a very important part is played by mineral compounds, including trace elements. In a number of cases their function is not fully determined, however, it is common knowledge that they produce a stimulatory effect on various physiological processes accompanying those transformations (Kabata-Pendias & Pendias, 1993). A process of great significance occurring in plants is biotransformation of nitrogen compounds, in which bioelements also play an important part. Among such elements are included mainly: molybdenum, iron, copper and manganese. The best known effect is the activity of molybdenum as activator of nitrate reductase. It is considered that iron, copper and manganese have their share in further stages of reducing nitrate ions (Buczek & Marciniak, 1990; Kretowicz, 1976; Kabata-Pendias & Pendias, 1993).

The main source of trace elements for plants is soil or water nutrient and, to a lesser degree, also outer environment (dust, precipitation). Plants react to both deficiency and excess of those components. In view of a steadily-increasing concentration of heavy metals in the environment a risk arises of their phytotoxic effect, which may result in disturbances of some physiological processes (Kabata-Pendias & Pendias).

The aim of this study was to trace relationships between the levels of nitrates and nitrites and endogenic contents of iron, copper and manganese in potato tubers.

2. Materials and methods

Studies were conducted on tubers of 16 cultivars of consumable potatoes, cultivated in the Experimental Station of Varieties Appraisal at Węgrzce near Cracow in the years 1991–1992. Soil and climatic conditions differed between years (Table 1).

Laboratory tests were made on 3 kg of tubers, which were washed, air-dried, peeled and comminuted mechanically. In the material prepared according to the norm, the levels of nitrates and nitrites were determined using a colorimetric method (Tyszkiewicz, 1986). The contents of iron, copper and manganese were determined using an atomic absorption spectrophotometer (Philips PU 9100) after dry mineralization of samples at 450°C.

The results obtained were analysed statistically by the method of two-way analysis of variance and correlation coefficients, *r*, were calculated, in which significance was verified with the Student's *t*-test (Krawontka & Bozyk, 1992).

3. Results and discussion

The level of nitrates in the studied potato cultivars was in the range of 61–843 mg kg^{-1} wet mass (Table 2)

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Table 1
Soil–climate conditions of grown potatoes

Year	1991	1992
Soil type	Very good wheath complex, brown loessial soil	
Soil pH	7.0	5.0
Soil richness (mg 100 g^{-1})		
P_2O_5	12.1	11.7
K_2O	10.5	10.0
Mg	8.9	17.4
Mean temperature (°C)	16.3	17.4
Total rainfall (mm)	359.7	203.5

Table 2
Content of nitrates in the studied potato cultivars (mg $NaNO_3$ kg^{-1})

Cultivar	Year of cultivar		Mean	Standard deviation	Significant differences at p =
	1991	1992			
Ronda	240	61	150	98	Non-significant
Jagna	206	260	233	31	0.01
Jagoda	172	118	145	30	0.01
Mila	342	290	316	29	0.01
Fala	623	86	354	295	Non-significant
Fauna	438	192	320	135	Non-significant
Heban	308	95	202	117	0.01
Ibis	202	139	171	35	0.01
Marta	128	86	107	24	Non-significant
Bzura	110	120	115	11	0.05
Kolia	143	71	107	40	Non-significant
Uran	466	105	231	198	Non-significant
Atol	843	173	508	367	Non-significant
Bryza	548	153	351	217	0.01
Irga	115	216	166	56	0.01
Elba	495	81	288	227	Non-significant
Mean	336	140	238		
Standard deviation	208	67		183	
F_o	956.0	162.2			
LSD[a]	19.6	15.6			

[a] LSD, least significant difference.

Table 3
Content of nitrites in the studied potato cultivars (mg $NaNO_2$ kg $^{-1}$)

Cultivar	Year of cultivar		Mean	Standard deviation	Significant differences at p =
	1991	1992			
Ronda	1.63	0.40	1.02	0.68	0.01
Jagna	1.70	1.27	1.49	0.29	0.05
Jagoda	3.43	0.27	1.35	1.75	0.01
Mila	2.53	0.80	1.66	0.98	0.01
Fauna	2.67	0.97	1.83	0.95	0.01
Heban	5.00	1.00	3.00	2.22	0.01
Ibis	4.00	1.43	2.71	1.41	0.01
Marta	2.37	1.17	1.77	0.68	0.01
Bzura	3.03	0.53	1.78	1.38	0.01
Kolia	2.03	1.30	1.77	0.40	0.01
Uran	4.53	1.73	3.13	1.54	0.01
Atol	4.60	1.30	2.95	1.82	0.01
Bryza	4.93	1.60	3.27	1.83	0.01
Irga	3.43	1.50	2.96	1.06	0.01
Elba	3.23	1.87	2.55	0.78	0.01
Mean	3.43	1.09	2.26		
Standard deviation	1.24	0.51		1.51	
F_o	66.88	33.13			
LSD[a]	0.444	0.252			

[a] LSD, least significant difference.

and that of nitrites 0.27–5.73 mg kg^{-1} wet mass (Table 3). The level of nitrates differed significantly between consecutive years of cultivation and a strict correlation was found in the contents of nitrates and nitrites in tubers (Table 7) (Cieslik & Sikora, 1998).

The content of iron in the studied potatoes was in the range of 0.30–2.20 mg 100 g^{-1} wet mass, averaging 0.67 mg 100 g^{-1} (Table 4). In the tubers of most cultivars under study the average content of iron corresponded to the lower limit of ranges cited in the literature (Kabata-Pendias & Pendias, 1993; Schick & Klinowski, 1961). The lower levels of iron in potatoes were ascertained by Krelowska-Kulas (1988). In our studies statistically significant differences in iron levels were found to be cultivar-dependent and in the majority of cultivars they also depended on the year of cultivation at $p = 0.01$. Variation in iron level between years of cultivation was statistically non-significant for only Jagoda, Fauna, Heban, Bzura and Atol varieties (Table 4). In the process of nitrate biotransformation the most pronounced is the role of iron, which is a component of one of the prosthetic groups of nitrate reductase, as well as of ferredoxin, an activator of enzymes participating in further stages of reduction (Buczek & Marciniak, 1990). It was found that vegetables displaying a considerable predisposition to nitrate accumulation assimilate more iron than the plants which do not accumulate those compounds, since this element is indispensable in the nitrate reductase synthesis (Harper & Paulsen, 1969a and b).

The correlation coefficient obtained is indicative of a certain correlation between the iron content and the level of nitrates in the studied potatoes ($r = -0.28$); however, this is statistically non-significant (Table 7).

In addition, statistical analysis showed the existence of a positive correlation between the iron and copper levels ($r = -0.33$ at $p = 0.01$) (Table 7).

The content of copper in the studied potatoes was in the range of 0.05–0.13 mg 100 g^{-1} wet mass product, averaging 0.092 mg 100 g^{-1}. The results obtained were consistent with literature data (Pendias, 1993; Krelowska-Kulas, 1988; Kabata-Pendias & Schick & Klinowski, 1961). Also, in the case of this element, a significant difference was found in its content, depending on potato cultivar and, in some cultivars (Jagna, Jagoda, Mila, Heban, Ibis, Bzura, Bryza, Irga), also depending on the year of cultivation (Table 5).

The statistical analysis of the result obtained showed a negative correlation between copper content and levels of nitrites, the correlation coefficient being $r = -0.34$ at

$p = 0.01$ (Table 7). Literature data reveal rather controversial opinions of the effect of this element on the nitrate reductase activity (Dias & Oliveira, 1996; Singh, Bharti & Kumar, 1994). It is assumed that, in view of an antagonism in relation to molybdenum as well as an indirect effect on the photosynthesis reduction, the higher concentrations of copper may unfavourably affect the activity of this enzyme (Baszynski & Krupa, 1995). It is suggested, however, that this element can be an activator of the nitrite reductase (Kretowicz, 1976). Our findings also indicate that concentration of copper ions in the medium of potato tubers is of significance for those transformations, and its fluctuations, even in the studied range, may affect the nitrite level in tubers.

Manganese content in tubers ranged from 0.05 to 0.30 mg 100 g^{-1} wet mass, averaging 0.090 mg 100 g^{-1}. The values obtained were close to the lower limit of ranges cited in the literature (Kabata-Pendias & Pendias, 1993; Schick & Klinowski, 1961). Statistical analysis showed significant differences in tuber manganese contents depending on cultivar and year of cultivation. Variation in manganese level between years of cultivations was statistically non-significant for only Jagna, Mila, Fala, Fauna and Ibis variety (Table 6).

Like copper, manganese is considered to be an activator of further nitrite ion reductase although its effect seems lesser and rather indirect (Harper & Paulsen, 1969; Mukhopadhyay & Shrama, 1991). A low correlation coefficient, between the content of manganese and the levels of nitrates and nitrites in the tubers under study, seems to confirm this indirect effect (Table 7). Variations observed in the levels of the studied elements between cultivars are indicative of a commonly-underlined variability of the investigated biological material.

Table 4
Content of iron in studied potato cultivars (mg 100 g^{-1})

Cultivar	Year of cultivar		Mean	Standard deviation	Significant differences at p =
	1991	1992			
Ronda	0.42	0.90	0.66	0.26	0.01
Jagna	0.48	0.30	0.39	0.10	0.01
Jagoda	0.55	0.50	0.53	0.06	Non-significant
Mila	0.43	0.40	0.41	0.02	0.01
Fala	0.60	0.50	0.33	0.06	0.01
Fauna	0.45	0.40	0.43	0.07	Non-significant
Heban	0.49	0.50	0.50	0.04	Non-significant
Ibis	0.49	1.30	0.90	0.44	0.01
Marta	0.47	2.20	1.33	0.44	0.01
Bzura	0.51	0.60	0.56	0.07	Non -significant
Kolia	1.03	0.80	0.92	0.13	0.01
Uran	0.46	0.60	0.53	0.08	0.01
Atol	0.44	0.40	0.42	0.03	Non-significant
Bryza	0.54	0.40	0.47	0.08	0.01
Irga	0.51	0.90	0.71	0.22	0.01
Elba	0.49	0.70	0.60	0.12	0.01
Mean	0.62	0.71	0.67		
Standard deviation	0.24	0.46		0.35	
F_o	101	47.5			
LSD[a]	0.069	0.108			

[a] LSD, least significant difference.

Table 5
Content of copper in the studied potato cultivars (mg 100 g^{-1})

Cultivar	Year of cultivar		Mean	Standard deviation	Significant differences at p =
	1991	1992			
Ronda	0.103	0.120	0.112	0.018	Non-significant
Jagna	0.087	0.070	0.078	0.010	0.01
Jagoda	0.057	0.100	0.078	0.025	0.01
Mila	0.073	0.110	0.092	0.020	0.01
Fala	0.080	0.080	0.080	0.006	Non-significant
Fauna	0.097	0.100	0.098	0.004	Non-significant
Heban	0.087	0.110	0.098	0.013	0.01
Ibis	0.087	0.130	0.108	0.024	0.01
Marta	0.087	0.100	0.093	0.010	Non-significant
Bzura	0.093	0.080	0.087	0.008	0.05
Kolia	0.103	0.100	0.102	0.010	Non-significant
Uran	0.090	0.090	0.090	0.006	Non-significant
Atol	0.080	0.080	0.080	0.006	Non-significant
Bryza	0.090	0.100	0.095	0.006	0.01
Irga	0.050	0.090	0.070	0.022	0.01
Elba	0.113	0.110	0.112	0.015	Non-significant
Mean	0.086	0.098	0.092		
Standard deviation	0.018	0.015		0.018	
F_o	7.561	38.4			
LSD[a]	0.017	0.004			

[a] LSD, least significant difference.

Table 6
Content of manganese in the potato cultivars (mg 100 g^{-1})

Cultivar	Year of cultivar		Mean	Standard deviation	Significant differences at p =
	1991	1992			
Ronda	0.090	0.100	0.095	0.006	0.01
Jagna	0.067	0.060	0.063	0.005	Non-significant
Jagoda	0.060	0.080	0.070	0.011	0.01
Mila	0.067	0.070	0.068	0.004	Non-significant
Fala	0.280	0.050	0.165	0.182	Non-significant
Fauna	0.067	0.060	0.063	0.005	Non-significant
Heban	0.090	0.080	0.085	0.006	0.01
Ibis	0.077	0.080	0.078	0.004	Non-significant
Marta	0.077	0.100	0.088	0.013	0.01
Bzura	0.060	0.060	0.060	0.000	0.01
Kolia	0.080	0.070	0.075	0.006	0.01
Uran	0.067	0.090	0.078	0.013	0.01
Atol	0.060	0.070	0.065	0.006	0.01
Bryza	0.067	0.390	0.228	0.177	0.01
Irga	0.050	0.080	0.065	0.016	0.01
Elba	0.090	0.080	0.085	0.006	0.01
Mean	0.084	0.095	0.090		
Standard deviation	0.067	0.077		0.073	
F_o	3.17	46.0			
LSD[a]	0.273	0.018			

[a] LSD, least significant difference.

Table 7
Correlation coefficients between determined components of potato tuber

Lp.	Tuber components	1	2	3	4	5
1	Nitrates	1.000	−0.70[c]	− 0.28[a]	0.10[a]	− 0.15[a]
2	Nitrites		1.00	− 0.19[a]	0.14[b]	− 0.34[c]
3	Iron			1.00	0.002[a]	0.33[c]
4	Manganese				1.00	0.13[–]
5	Copper					1.00

[a] Statistically non-significant.
[b] Statistically significant at $p = 0.05$.
[c] Statistically significant at $p = 0.01$.

Each of the tested microelements is indispensable for plant life, fulfilling a defined part in a number of biochemical processes occurring in plants. In the investigation, presented here, on the effect of microelements on transformations of nitrogen compounds in potatoes, the role of copper proved to be the most pronounced.

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