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Presence of Toxic Matter in Edible Vegetable Parts

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Abstract: The long-term research work on the presence of toxic matter, nitrates and heavy metals in some vegetable crops was presented in the paper. The experiments were carried out under production conditions in protected and open field conditions, on the soil with different contamination level with heavy metals and differing nitrogen amounts being fertilized.

Based upon the long-term research, it may be concluded that nitrate content was higher in the outer lettuce leaves in the plastic house than that in those in the open field. With the increase in nitrogen rate, the content of nitrates increased, too, in the cabbage, similarly to that in spinach in which genetic tolerance to their accumulation was also manifest.

The content of toxic heavy metals was found to be somewhat higher than that of normal values, but still being within permissible values in view of human nutrition.

Key words: nitrates, heavy metals, vegetables, plastic house, open field.

Introduction

Intensive vegetable production, which has been highly pronounced in recent years both, in and out of the country, has resulted in certain adverse effects, as well. Namely, a good quality seed, a high technological production level, coupled with fertilization and disease and pest control, are unavoidable to achieve high yields. However, through fertilization, high amounts of fertilizers and chemicals are introduced into the soil, thereby polluting it to a great extent. Harmful matter can reach soil by man' s impact, just as being with nitrates and heavy metals. When found

in greater amounts in the soil, the pollutants are readily taken up by plants, which become polluted, as well. So obtained products are of a lower quality and even threaten humans to be affected by various and sometimes cancerous diseases. It is a well-known fact how poisonous the effects of the highly introduced nitrate and heavy metal amounts can be for man's health (Vajagic et al., 1986), hence, it seems important to study whether the content of harmful matter is within or beyond the permissible concentrations.

In addition to regulating the amounts of chemicals entering into the soil, a few authors think that contents of heavy metals and nitrates in the vegetables depend on the cultivar, its genetic potential and on the environmental conditions, as well (Zucenko, 1980; Stevanovic et al., 2001). This content can vary depending on the plant part (root or leaf), leaf arrangement (outer or inner) and on the production mode (open field or plastic house), too.

Bearing plant nutritive value and its rank in the appropriate diet in mind, we aimed at optimal rates of nitrogen fertilizers for attaining high and stable good quality yields, which, as such, would have no adverse effect on the increased nitrate content in the soil. Also, we tended to determine the content of heavy metals in the soil, which could be tolerated and taken up by plants, without any inhibitory or plant toxic impact on the normal plant development.

The paper is mainly devoted to studying responses of vegetable plants (lettuce, radish and carrot) to differing contents of heavy metals in the soil as well as those of cabbage, lettuce and spinach to introducing of the varying nitrogen fertilizer amounts.

Nitrate content in edible vegetable parts

The nitrate contents in the plants are influenced by many external and internal factors. Of the external ones, the most significant seem to be the content of mineral nitrogen forms in the soil, the amount of nitrogen fertilizers introduced in the soil during vegetation season of the particular crop and environmental conditions over research. Of the internal factors, the most significant ones seem to be the plant affinity to nitrate accumulation as well as the varietal specificity. Studying parameters either individually or as a whole was made with lettuce, cabbage and spinach which belong to nitrate accumulation prone vegetables grown in plastic house or in the open field, with results worked out and unified in the paper.

Spinach has been found to be prone to nitrate accumulation in edible parts, hence its selection paved the way for new genotypes, which are genetically tolerant to accumulation of harmful matter and have a shorter petiole containing abundance of the nitrates. When studying tolerance of the various spinach cultivars to the nitrate content, Pavlovic et al., (1998) set up a trial with four spinach cultivars fertilized with three CAN amounts (50, 100, 200 kg N/ha). Nitrate content significantly varied depending on the cultivar, plant organ (leaf or petiole) and especially on differeent nitrogen fertilizer treatments, (tab.1.), too. Comparing these genotypes, the hybrid Triathlon was found to have the highest affinity to nitrate accumulation in edible part (averaging 507.3 mg/kg), while that of Vivat had the lowest one (averaging 321.5 mg/kg). Thus, some recent knowledges of the nitrate content as a genetic trait, determined by cultivar specificity (Zucenko, 1980; Barner, 1980; Breimer, 1982; Pavlovic, 1997) have been confirmed.

The increasing nitrogen amounts are believed to have directly induced an increase in nitrate content in spinach, with the highest values recorded with the highest N amount (200 kg/ha), being in agreement with the previous researches of Zucenko (1980) and Breimer (1982).

Tab.1. Nitrate Content in Spinach (mg/kg dry matter)

Cultivar hybrids	Vari-ants	Leaf		Leaf stem		Total contet	Index
		NO_3-N	Index	NO_3-N	Index		
Matador	1	14.0	100	37.3	100	51.3	100
	2	112.0	800	317.3	850	429.3	836
	3	154.0	1100	392.0	1050	546.0	1064
	4	210	1500	448.0	1201	658.0	1282
Average		122.5		298.6		421.1	
Triptiek	1	14.0	100	205.3	100	219.3	100
	2	75.6	540	250.1	122	325.7	148
	3	190.4	1360	354.7	173	545.1	249
	4	299.6	2140	466.7	227	766.3	349
Average		144.9		319.2		464.1	
Triathlon	1	42.0	100	44.8	100	86.8	100
	2	117.6	280	429.3	958	546.9	630
	3	238.0	567	429.3	958	667.3	769
	4	280.0	666	448.3	1000	728.3	839
Average		169.4		337.8		507.3	
Vivat	1	14.0	100	18.7	100	32.7	100
	2	98.0	700	208.5	1115	306.5	937
	3	104.0	743	317.3	1697	421.3	1288
	4	182	1300	343.5	1837	525.5	1607
Average		99.5		222.0		321.5	

As a vegetable crop of a comparatively short vegetation period, lettuce is abundantly and only fresh used in man's nutrition, especially at the time when other vegetables are in short supply on the market. Therefore, the exact amounts leading to a greater yield, and showing no negative effect on the higher nitrate uptake and accumulation in edible lettuce parts, should be revealed. As far as differing CAN amounts (50, 100 and 200 kg N/ha) are concerned, Pavlovic et al., (1997) found that increased N fertilizer directly increased the average nitrate content in the lettuce by 53-250% in open field and by 42-123% in the plastic house, respectively, compared to the control treatment (tab.2.).

Tab.2. The Effect of Fertilizer on Nitrate Content in Lettuce Leaf (mg/kg fresh mass)

Outer leaf				Inner leaf				Average per head of lettuce			
Plast. hous.	index	Trial field	index	Plast. house.	index	trial field	index	Plast house.	index	Trial field	index
42.0	100	88.7	100	88.7	100	135.3	100	65.3	100	112.0	100
107.3	255	163.3	184	93.3	105	154.0	114	100.3	153	158.6	142
191.3	455	191.3	216	126.0	142	162.0	120	158.6	243	176.6	158
315.0	750	317.8	358	142.8	161	182.9	135	228.9	350	250.0	223

Nitrate accumulation was found to be in both production modes noticeably higher in the outer green leaves than that in the inner ones, with the most expressed differences with the highest N amount (200 kg/ha) and raising under plastic house conditions. However, average nitrate contents were recorded to be visibly below upper permissible limit of standards of the European Union, and amounted to 2500 mg/kg (Lazic, B. et al., 1994).

Study results of Stevanovic et al., (2001) about nitrate content in two various lettuce cultivars (domestic and foreign) grown in plastic house and in open field are strong evidence of the previously presented data. Namely, based on these results (tab.3.), it may be concluded that, beside low mineral N content in soil, nitrate content was significantly higher in lettuce grown in plastic house than that of lettuce grown in open field. Regarding the differences in leaf arrangement, nitrates were higher in the outer than those in the inner leaves.

In addition, greater nitrate accumulation was established in domestic cultivar Nansen, compared to the Holland cultivar Sany, i.e. 2704 mg/kg in Nansen and 2485 mg/kg in Sany, respectively. This can be explained by breeding of the new generations of foreign cultivars with genetically inherent tolerance to nitrate accumulation.

Tab.3 Nitrate Content in Lettuce Leaf (mg/kg dry matter)

Cultivation practice	Leaf characteristic	Cultivar	
		Nansen	Sany
Plastic house	Outer	3360	3220
	Inner	2976	2520
Open field	Outer	2660	2520
	Inner	1820	1680

Similar studies were performed with cabbage, which belongs to the nitrate accumulation prone vegetables, and has a high significance and usability in man nutrition, both, fresh and processed. The effect of increasing N amounts on the nitrate content in lettuce head, was followed in this case. Previous knowledge of the higher nitrate content with a greater N amount, ranging from 525 to 1596 mg/kg dry matter, at which even the highest N amounts (300 N/ha) remained within permissible nitrate contents according to standards of the European Union (tab.4.), were confirmed by the data obtained.

Tab 4. The Effect of Fertilizer Amount on Nitrate Content in Lettuce Head (mg/kg dry matter)

Fertilizing variants	Nitrate content	Index
Control	525	100
100 kg N/ha	840	160
200 kg N/ha	1036	197
300 kg N/ha	1596	304

The Content of Heavy Metals in Vegetable Edible Parts

The existence of heavy metals (microelements and toxic metals) in the soil in greater amounts can give rise to a higher uptake by plant, which has adverse effects on the food quality. This is particularly important knowing that 90% toxic matter introduced in man's organism stem from the food itself. In recent years, heavy metals have been found to reach soil in large amounts. Thus, a few vegetable crops (lettuce, radish and carrot) grown on the soils being variously contaminated with heavy metals have been studied to get data on the inter-relationships of these toxic matter in the soil and their concentrations in the edible vegetable parts.

Stevanovic et al., (2001) studied the content of heavy metals in the leaves of the two lettuce cultivars, grown in plastic house and in the open field (tab.5.) on the soil supplied with heavy metals up to the maximally permissible limits. The results indicated a higher content of some useful heavy metals (Fe, Mn, Zn) in the domestic cultivar Nansen, with outer leaves, having accumulated higher amounts of Fe and Mn than the inner ones did, whereas Zn content seemed to be higher in the inner than in the outer ones. The content of toxic metals (Cr, Pb, Ni) was somewhat above the usual values, but, being within the allowable ones as for human food.

Tab.5 The Content of Heavy Metals in Lettuce Leaf (mg/kg dry matter)

a) Domestic cultivar (Nansen)

Cultivat. practice	Leaf characteristic	Fe	Mn	Zn	Cu	Co	Cr	Pb	Ni	Cd
Plastic house	Outer	135	39	24	7	1	4	5	2	1
	Inner	93	20	43	8	1	4	1	3	1
Open field	Outer	877	51	31	8	2	5	6	9	1
	Inner	117	20	62	13	1	6	1	6	1

b) Dutch cultivar (Sany)

Cultivat practice	Leaf characteristic	Fe	Mn	Zn	Cu	Co	Cr	Pb	Ni	Cd
Plastic house	Outer	128	52	23	6	1	3	5	2	1
	Inner	92	20	48	9	1	2	3	3	1
Open field	Outer	233	47	24	9	2	4	1	2	1
	Inner	109	17	53	9	1	3	1	3	1

So obtained values have been found to significantly vary from the established contents of all the metals (except Cd) in the lettuce grown in vegetation dishes on the same soil. The values of Fe, Mn and Zn became two- or threefold greater (tab.6. Stevanovic et al., 2001) while, comparing to their content on the strongly contaminated soil, their values were even ten times higher than the permissible ones for human food.

These studies also deal with effects of heavy metals in the soil and their uptake and accumulation level in different plant organs (root, leaf) of the individual vegetable crops (radish and carrot). Also, higher amounts of metals were taken up in the first two soils studied, with higher accumulation noticed in the leaf than that in edible root, which may be considered as an advantage because the root is used in human diet. Due to toxic effect of heavy metals on the extremely contaminated soil, no edible root was formed and no plant production managed either.

Tab.6. The Content of Heavy Metals in Vegetables (mg/kg dry matter)

a) Lettuce

Soil	Organ	*Fe*	Mn	Zn	Cu	Co	Cr	Pb	Ni	Cd
Garden	Leaf	487	94	96	489	3	5	10	5	1
Beside highway	Leaf	511	55	146	755	2	4	6	5	1
Strongly contaminated	Leaf	1210	386	3280	482	5	36	94	32	6

b) Radish

Garden	Leaf	379	45	145	783	2	6	8	5	1
	Root	352	17	40	43	1	5	3	3	1
Beside highway	Leaf	1615	56	84	289	3	6	9	12	1
	Root	403	16	47	44	1	6	4	5	1
Strongly contaminated	Leaf	2725	73	3425	728	2	10	43	15	10

c) Carrot

Garden	Leaf	3228	117	83	349	4	15	13	20	1
	Root	275	25	21	11	2	4	2	4	1
Beside highway	Leaf	427	44	113	630	1	1	8	6	1
	Root	190	11	26	18	1	2	1	2	1
Strongly contaminated	Leaf	3302	103	2881	829	1	12	38	12	9

Conclusion

Based upon responses of the vegetables (lettuce, radish and carrot) to a differing content of heavy metals in the soil, as well as upon those of cabbage, lettuce and spinach to introducing of differing N fertilizer amounts, the following conclusions may be drawn:

- Higher N fertilizer amounts elevated nitrate contents in the lettuce much more in the plastic house than it happened in the open field. A higher nitrate accumulation was also established in the outer than in the inner leaves, which can be of great use in practice.

- In spinach, hybrid Vivat was found to achieve the highest yield and exhibited the greatest tolerance to nitrate accumulation. However, the hybrids of Triptiek and Triathlon were prone to nitrate accumulation. In order to produce as healthy food as possible, spinach selection and breeding towards forming of genotypes with shorter petioles and a more delicate venation where the nitrates are mostly accumulated should be attempted.

-Similar dependence was established in the cabbage, where the nitrate content increased with the increase in N rate being within allowable limits prescribed by the standards of the European Union.

- The content of useful microelements (Fe, Mn and Cu) in lettuce leaf was found to depend on production mode, cultivar and on distribution of the leaves, as well, with somewhat higher content determined in the lettuce grown in the open. Higher content of Fe and Mn was found in the outer leaves and that of Zn and Cu in the inner ones. The content of toxic heavy metals (Cr, Pb and Ni) was somewhat higher than that of the usual values, but still being within the allowable limits in view of human diet.

- Depending on the degree of soil contamination, the vegetable crops under way (lettuce, radish and carrot) are endangered by heavy metal accumulation, especially in the leaves. This proneness can display an adverse phyto-toxic effect on the normal plant growth and development. The distribution of heavy metals among plant organs may be of great practical importance when using radish and carrot in human diet, i.e. their edible parts.

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PRISUSTVO ŠTETNIH MATERIJA U JESTIVIM DELOVIMA NEKIH POVRTARSKIH VRSTA

- originalni naučni rad-

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Rezime

U ovom radu je kod različitih povrtarskih kultura proučavano prisustvo štetnih materija (nitrata i teških metala).

Eksperimenti su bili postavljeni u plasteniku i na otvorenom polju, na zemljištima koja su se razlikovala po hemijskom sastavu i sadržaju teških metala. Pored ovoga, praćene su i reakcije različitih sorti (domaćih i inostranih) na usvajanje i sklonost ka akumulaciji nitrata zavisno od primene azotnih đubriva.

Dobijeni rezultati pokazuju značajnu zavisnost akumulacije nitrata u jestivim delovima povrća kao posledica primene rastućih doza azotnih đubriva, pri čemu su koncentracije nitrata uvek bile u okviru dozvoljenih granica. Sadržaj teških metala je takođe zavisio od sadržaja ovih elemenata u zemljištu i varirao je zavisno od vrste povrća.