Content of Heavy Metals in the Reed Canarygrass (*Phalaris Arundinacea* L.) in the First Year of Harvest

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***Abstract* - One of the major factors in achieving more biofuel is the amount of crop yield, but that is not synonymous with the yield quality. Plants are contaminated by heavy metals not only through the soil, but also from atmospheric pollution. The aim of this research was to establish the amount of heavy metals in the dry matter of reed canarygrass (*Phalaris arundinacea* L.). The Marathon variety of reed canarygrass was studied with two sowing periods and four N-fertilizer rate applications. The concentration level of arsenic (As), cadmium (Cd), lead (Pb) and titanium (Ti) in the samples of reed canarygrass were analysed with the coupled plasma optical emission spectrometer Perkin Elmer 2100 DV. The samples of reed canarygrass taken in April had a greater concentration of As, Cd, Pb, which means that the plants absorb the heavy metals also from the snow covering. The first year yield of reed canarygrass established a fundamental negative correlation between the amount of As, Cd, Pb and the ash content. The samples taken in April have a greater heavy metal contamination, than the samples taken in October. The sowing period fundamentally affected the concentration of lead in reed canarygrass samples, but the level of N-fertilizer rate application affected the amount of cadmium and arsenic.**

***Keywords* - *Phalaris arundinacea* L., N-fertilizer rate, As, Cd, Pb, Ti.**

I. Introduction

Reed canarygrass is suitable for biomass production, as the production cycle exceeds 10 years (Lazdiņa et al., 2008; Energy..., 2009), and cultivated plants established for a long time in the same area have a beneficial effect on the surrounding environment, as they minimise soil erosion and improve soil quality (Adamovičs et al., 2007; Sanderson et al., 2008; Wrobel et al., 2009). One of the major factors in achieving more biofuel is the amount of crop yield, but that is not synonymous with the yield quality.

The production of wood-pulp pellets requires the addition of biomass plants, for example reed canarygrass. It is important that the plants used in pellet production have no or very low heavy metal concentration. That is important, as the end product of burning the pellets which are the ashes, can be used as a mineral fertiliser.

Increased mineral fertiliser application rates, the contamination of rainfall and other pollutants cause the contamination of ground-water with nitrates, the accumulation of ballast material, inclusive of toxic elements, which fundamentally worsen the soil quality and fertility (Минеев, 1984; Bramley et al., 1990). Plant contamination with heavy metals does not only happen through the soil, but also from air contamination, which changes the physiological (also the photosynthetic) activity (Bramley et al., 1990; Пастухова, 2008). As plants accumulate heavy metals on a systematic basis, with time the concentration becomes toxic to the plants (Husain et al., 2002). Different mineral fertiliser rates not only mobilise separate soil nutrients, but also connect them, producing unacceptable connections for the plants (Минеев, 1984). The term "heavy metal" denotes metals with an atomic weight above 40 u.

The normal concentration of heavy metals in plants is as follows: arsenic - 0.1 - 1.0 mg/kg of dry matter (DM), cadmium - 0.05 - 0.2 mg/kg of DM, lead - 0.1 - 5.0 mg/kg of DM (Минеев, 1984; Alaru et al., 2009). Cadmium hinders plants in absorbing necessary nutrients, but lead slows down the absorption of magnesium, potassium and phosphorus (Минеев, 1984).

The objective of the research: to estimate the amount of heavy metals in the dry matter of reed canarygrass (*Phalaris arundinacea* L.).

II. Materials and Methods

The object of the research - reed canarygrass (*Phalaris arundinacea* L.) is a part of the stalkgrass (*Poaceae*) family and is a perennial tendril shooting cover grass C3.

Three repeat experiments in the field with reed canarygrass variety 'Marathon' was carried out at the Agricultural Science Centre of Latgale in sod-podzolic loamy soil (the organic content of the soil - 5.2%, pH KCl - 5.8, P_2O_5 - 20 mg/kg, and K_2O - 90 mg/kg of soil).

The area of the plots was 16 m^2, the location of the plots was randomised. The reed canarygrass was sown after bare follow. Before sowing a complex fertiliser was applied N:P:K-5:10:25-400 kg/ha. The nitrogen supplementary fertiliser rates: N0 - control, N30, N60, N90 kg/ha. Reed canarygrass variety "Marathon" was sown on the 12.08.2008 (henceforth 'Marathon' 08) and 29.04.2009 (henceforth 'Marathon' 09). Nitrogen (N) supplementary fertiliser was given to "Marathon" 08 on the 20.05.2009, and on the 22.07.2009 for 'Marathon' 09.

The dry matter samples were taken from 0.25 m^2 areas on three replications in 12.10.2009 and 06.04.2010. The ash content was established on 3 occasions in the Chemistry Laboratory of the Rezekne Higher Education

Institution with the accelerated standard method. Arsenic (As) cadmium (Cd), lead (Pb) and titanium (Ti) concentrations in the reed canarygrass samples were established with the inductively coupled plasma optical emission spectrometer Perkin Elmer Optima 2100 DV.

The meteorological conditions for agriculture (Figures 1 and 2) during 2009 the plant growth period had a marked deficit in rainfall. The May air temperature was close the long-term average, but the amount of rainfall was a third of the long-term average. In July the mean air temperature for the 24-hour period corresponds to the mean long-term indicators. On 13 April 2010 the reed canarygrass plant growth was renewed.

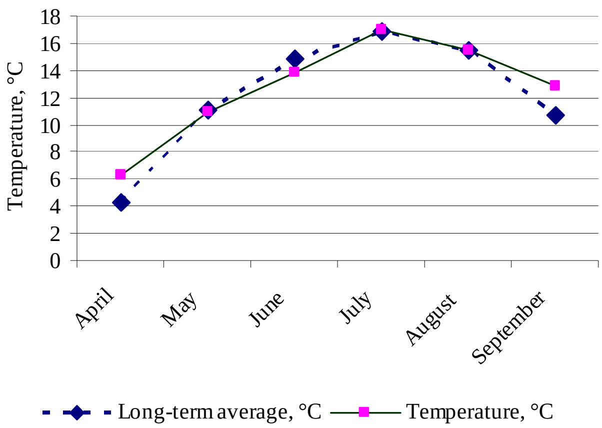

Fig.1. Average air temperature in 2009 from Viļāni, °C.

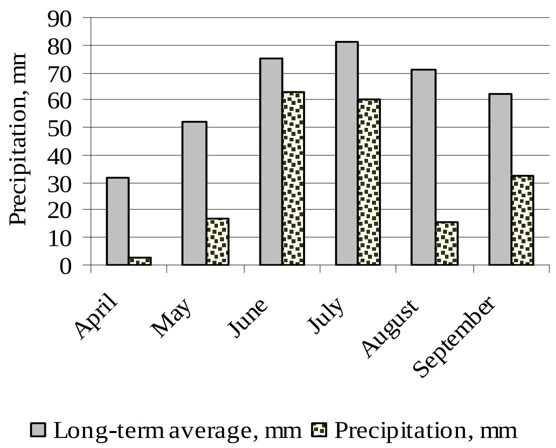

Fig. 2. Sum of precipitation in 2009 from Viļāni, mm.

The trial data were processed using correlation, regression and variance analyses (ANOVA) and descriptive statistics. The means are presented with their LSD test.

III. Results and Discussion

Arsenic also gets to plants from pesticides. Therefore the period when the samples were taken fundamentally influences ($p<0.05$) on the arsenic level in reed canarygrass for the first year yield (Figure 3). The least amount of arsenic was in the October's sample, where the nitrogen supplementary fertiliser was not used. Arsenic content did not exceed 1.0 mg/kg, but also was not less than 0.1 mg/kg.

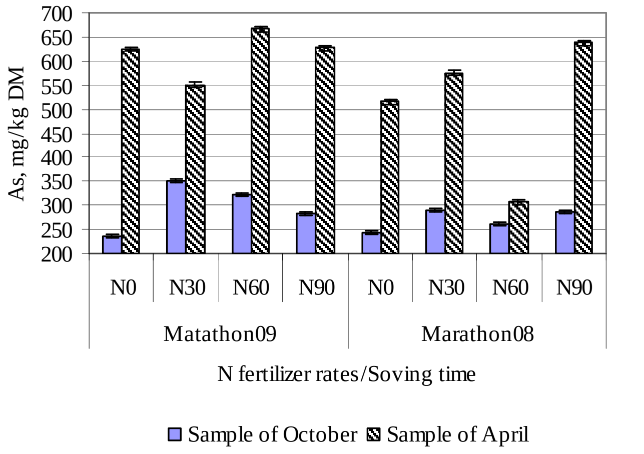

Fig.3. Arsenic (As) content in reed canarygrass yield of first year depending on N supplementary fertiliser rate and sowing time, mg/kg DM.

The arsenic content was influenced by almost all N supplementary fertiliser rates, as well as by the interactivity between the sowing period and the N supplementary fertiliser rates (Table 1).

TABLE 1

ARSENIC CONTENT PROPORTIONS FOLLOWING INFLUENCING FACTORS ($p<0.001$), %

Factors	**Sample of October**	**Sample of April**
Sowing time (factor A)	14.6	25.4
N supplementary fertilizer rate (factor B)	64.4	23.0
Interactivity between factors A and B	20.9	51.6

Regression analysis shows that arsenic (y) and ash content (x) are related. The analysis (n=16) shows that from each ash percent increase, the arsenic content decreases by 30.45 mg/kg DM (Figure 4).

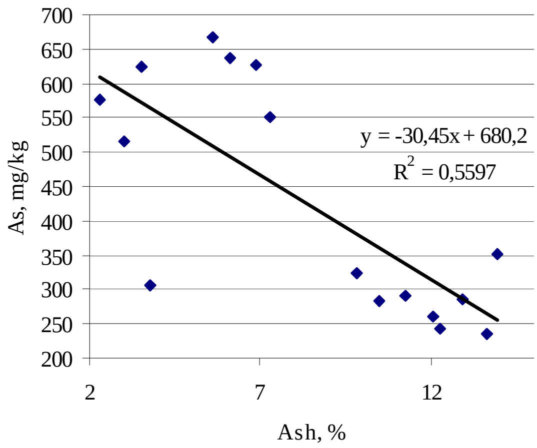

Fig. 4. The interaction ($p<0.001$) between average arsenic (As) and average ash content of reed canarygrass.

Cadmium is not fundamentally required by plants or animals, therefore the cadmium concentration has not been established when there has been a lack of cadmium (Bramley, 1990).

Cadmium compounds can be found in diesel fuel. Small amounts of cadmium are dangerous and it has a long elimination period - 30 years. The plants accumulate the cadmium particles from the air and with roots from the soil (Bramley, 1990).

The cadmium content in the April's samples of reed canarygrass exceeded 0.2 mg/kg DM, but it was not observed in the samples from the 2009 sown variety 'Marathon'. Variety 'Marathon' (sown in 2008) had a longer development period and, consequently, larger root system, therefore the higher the amount of Cd intake.

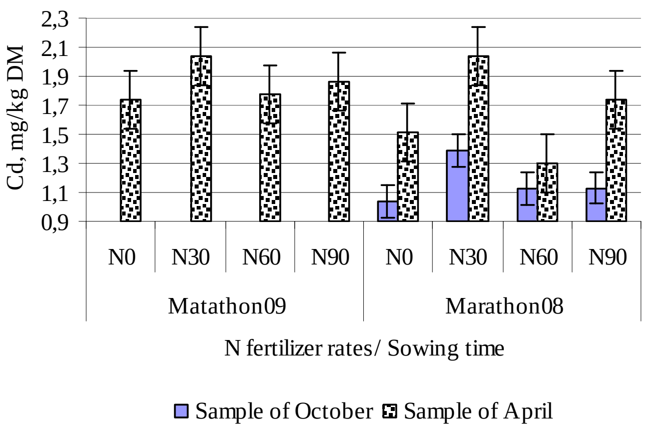

Fig. 5. Cadmium content (Cd) in reed canarygrass first year yield depending on N supplementary fertiliser rate and sowing time, mg/kg DM.

Cadmium content is not influenced by N supplementary fertiliser rate amounts (Минеев, 1984). In our findings the amount of nitrogen supplementary fertiliser had a fundamental significance in the samples taken in April, but the samples taken in October – not (Table 2).

TABLE 2

CADMIUM CONTENT PROPORTIONS FOLLOWING INFLUENCING FACTORS, %

Factors	Sample of October	Sample of April
Sowing time (factor A)	97.3**	18.2*
N supplementary fertilizer rate (factor B)	1.2	62.1**
Interactivity between factors A and B	1.2	13.0*

**$t_{fakt.} > t_{0.001}$, *$t_{fakt.} > t_{0.05}$

Regression analysis shows, that cadmium (y) and ash content (x) are related. Analysis (n=16) shows that with each ash percent increase, the amount of Cd decreases by 0.13 mg/kg DM (Figure 6).

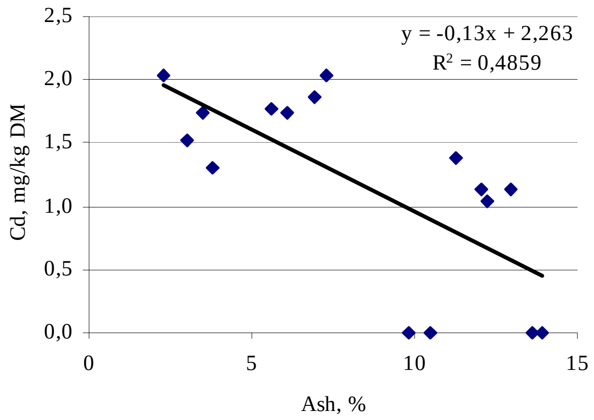

Fig. 6. The interaction ($p<0.05$) between average Cd and average ash content of reed canarygrass.

A tendency has been observed, that plants increase the absorption of cadmium if lead is present (Минеев, 1984). That is confirmed by our findings, which found a strong positive correlation (n=16; r=0.89; $p<0.001$) between Cd and Pb, and between Cd and As a middling positive correlation (n=16; r=0.73; $p<0.05$) was also established. These metals are phytotoxic, especially as they can interact with various elements in a synergistic and antagonistic way, which is also dependent on the soil pH level (Neuschütz et al., 2005)

Arsenic, cadmium and lead are part of various artificial fertilisers (Минеев, 1984). Evaluating the cadmium levels in plants the following need to be taken into account: the history of fertiliser application in the field, the organic content of the soil, the way the field has been cultivated, the climatic conditions, the soil quality (Bramley, 1990). Plant growth in 2009 was noted reduced rainfall (Figure 2). It must be noted that the concentration of heavy metal is less in the plants than in the soil (Strašil et al., 2010).

The amount of lead in the reed canarygrass sowings was fundamentally influenced by the sowing period ($p<0.05$) (Figure 7). The findings did not show a fundamental N-supplementary fertiliser amount as a factor of significance (Figure 7; Table 3). This indicates that the plants have absorbed the heavy metal from the snow cover, on which the particles of heavy metal had settled.

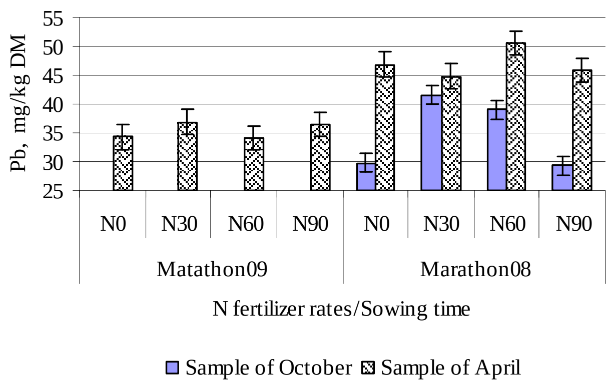

Fig. 7. Lead content (Pb) in reed canarygrass first year yield depending on N supplementary fertiliser rate and sowing time, mg/kg.

The lead content in plants was influenced by the sowing period - more than 90% (Table 3). That means that the longer the plants grew, the more they absorbed lead.

TABLE 3

LEAD CONTENT PROPORTIONS FOLLOWING INFLUENCING FACTORS, %

Factors	Sample of October	Sample of April
Sowing time (factor A)	95.3**	90.6**
N supplementary fertilizer rate (factor B)	2.3	1.2
Interactivity between factors A and B	2.3	7.2*

$^{**}t_{fakt.} > t_{0.001}$, $^{*}t_{fakt.} > t_{0.05}$

Regression analysis shows, that lead (y) and ash content (x) are related. Analysis (n=16) shows that with every ash percent increase, the lead content decreases by 2.919 mg/kg DM (Figure 8).

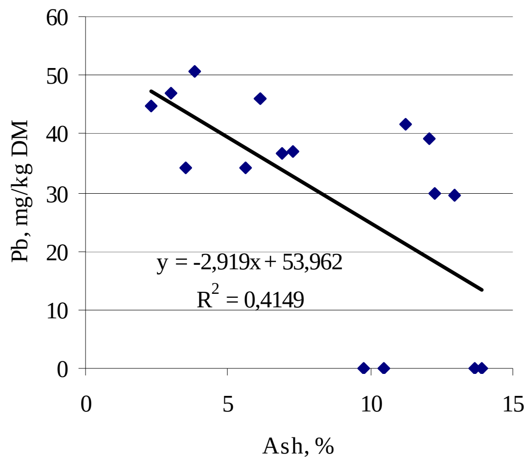

Fig. 8. The interaction (p<0.05) between average Pb and average ash content of reed canarygrass.

Titanium gets to plants in various ways: from the ground-water, from metal instruments, etc.

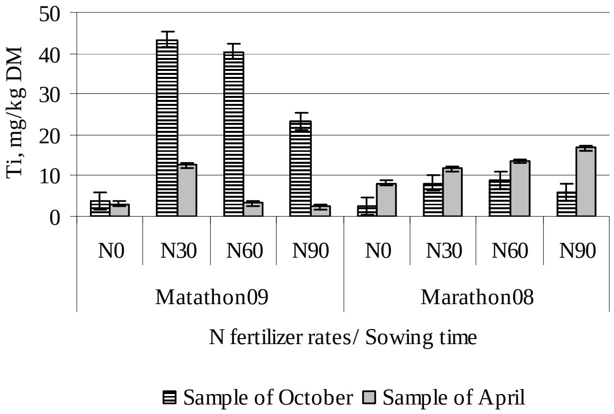

Fig. 9. Lead content (Pb) in reed canarygrass first year yield depending on N supplementary fertiliser rate and sowing time, mg/kg DM.

The titanium content influenced all three factors similarly (Table 4).

TABLE 4

TITANIUM CONTENT PROPORTIONS FOLLOWING INFLUENCING FACTORS (p<0.001), %

Factors	Sample of October	Sample of April
Sowing time (factor A)	47.1	48.5
N supplementary fertilizer rate (factor B)	34.2	20.6
Interactivity between factors A and B	18.5	30.6

Regression analysis shows, that titanium (y) and ash content (x) are not linked (Fig.10).

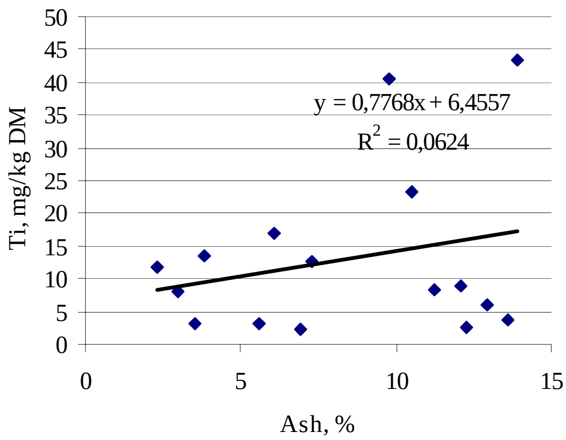

Fig. 10. The interaction between average Ti and average ash content of reed canarygrass.

The field trial areas are about 500 metres from the A 12 main road, and therefore one must assume, that the longer the plants are growing in the field, the greater will be pollution of the plants by cadmium, arsenic, lead and titanium.

Lead persistences in the soil and contributes to corrosion (Lu, 2005). Lead and cadmium in combination with zinc form corrosion products (Roberge, 1999; Lu, 2005). The plants take heavy metals during growth period, therefore good growing conditions must be most advantageous to reduce the HM in plants. Heavy metals adversely affect the quality of the canary reedgrass. A concentration of heavy metals in plants is less with the fertilizer rate N0 kg/ha.

IV. CONCLUSIONS

The spring samples of reed canarygrass had a greater amount of As, Cd and Pb and that means that the plants absorb the heavy metals also from the snow covering. The first year yield of reed canarygrass has shown a basic negative relationship between the amount of As, Cd and Pb and the ash content. The sowing time had significantly influence on the lead content in the reed canarygrass samples, but N supplementary fertiliser rates - the cadmium and arsenic content.

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Liena Poiša, Aleksandrs Adamovičs, Rasma Platače. Smago metālu daudzums miežabrāļa (*Phalaris arundinacea* L.) pirmā gada ražā
Raža ir viens no svarīgākajiem faktoriem, lai iegūtu vairāk biokurināmā. Bet ražas lielums ne vienmēr ir sinonīms kvalitatīvai ražai. Augu saindēšanās ar smagajiem metāliem notiek ne tikai caur augsni, bet arī no piesārņotā atmosfēras gaisa. Pētījuma mērķis: noteikt smago metālu daudzumu miežabrāļa (*Phalaris arundinacea* L.) pirmā gada ražai. Pētījuma objekts: miežabrālis (*Phalaris arundinacea* L.) ir stiebrzāļu (*Poaceae*) dzimtas daudzgadīga stīgotāja virszāle C3. Lauka izmēģinājumi trijos atkārtojumos ar miežabrāļa šķirni 'Marathon' ierīkoti velēnu - podzolētā smilšmāla augsnē (organiskās vielas saturs augsnē – 5.2%, pH - 5.8, P_2O_5 - 20 mg/kg, K_2O - 90 mg/kg). Miežabrāļa šķirne 'Marathon' tika iesēta 12.08.2008. (turpmāk tekstā 'Marathon'08) un 29.04.2009. Slāpekļa (N) papildmēslojums 2008. gada augustā sētajai šķirnei 'Marathon' dots 20.05.2009., bet 2009. gadā sētajām šķirnēm – 22.07.2009. Viena lauciņa platība 16 m^2. Arsēna (As), kadmija (Cd), svina (Pb) un titāna (Ti) koncentrācija miežabrāļa paraugos noteikti ar induktīvi saistītās plazmas optiskās emisijas spektrometru Pernin Elmese Optima 2100 DV. Aprīlī novāktajā miežabrāļa ražā bija lielāks As, Cd, Pb daudzums, nekā oktobrī novāktai. Tas nozīmē, ka augi smagos metālus uzņem arī no sniega segas. Miežabrāļa pirmā gada ražai konstatēta būtiska negatīva sakarība starp As, Cd, Pb daudzumu un pelnu saturu. Sējas laiks visbūtiskāk ietekmēja svina saturu miežabrāļa ražā, bet N papildmēslojuma normas – kadmija un arsēna daudzumu. Starp Cd un Pb tika konstatēta cieša pozitīva korelācija (n=16; r=0.89; p<0.001), un starp Cd un As arī tika konstatēta pozitīva vidēji cieša korelācija (n=16; r=0.73; p<0.05). Tā kā arsēnu, kadmiju un svinu satur dažādi minerālmēslojumi un pesticīdi, tad kā būtisks faktors parādās N papildmēslojuma normas ietekme. Izvērtējot kadmija nokļūšanas iespējas augos, jāņem vērā: lauka mēslošanas vēsture, organiskās vielas saturs augsnē, lauku apsaimniekošanas veids, klimatiskie apstākļi, augsnes īpašības.

Лиена Пойша, Александр Адамович, Расма Платаче. Количество тяжёлых металлов в двукисточнике тростниковидном (*Phalaris arundinacea* L.) в первый год урожая
Урожай является одним из наиболее важных факторов для получения как можно большего объёма биотоплива. Но величина урожая не всегда является синонимом качества урожая. Отравление растений тяжёлыми металлами происходит не только через почву, но и из загрязнённого атмосферного воздуха. Цель исследования: определение содержания тяжёлых металлов в двукисточнике тростниковидном (*Phalaris arundinacea* L.) в первый год урожая. Объект исследования: двукисточник тростниковидный (*Phalaris arundinacea* L.) – это многолетняя верховая трава семейства злаковых (*Poaceae*) C3. Полевые опыты с сортом двукисточника тростниковидного 'Marathon' в трёх повторностях были проведены в дерново-подзолистой суглинистой почве (содержание органический веществ в почве – 5.2%, pH - 5.8, P_2O_5 - 20 мг/кг, K_2O - 90 мг/кг). Сорт двукисточника тростниковидного 'Marathon' был засеян 12.08.2008 года (далее в тексте 'Marathon'08) и 29.04.2009. Азот в качестве дополнительного удобрения был подан 20.05.2009. на сорт 'Marathon', засеянный в августе 2008 года, и 22.07.2009 – на сорт, засеянный в июле 2009 года. Площадь одной делянки - 16 m^2. Концентрация мышьяка (As), кадмия (Cd), свинца (Pb) и титана (Ti) в образцах двукисточника тростниковидного были определены индуктивно связанным плазменным оптическим эмиссионным спектрометром Pernin Elmese Optima 2100 DV. В апреле в образцах двукисточника тростниковидного было большее содержание As, Cd, Pb, что означает, что тяжёлые металлы растения могут получать из снежного покрова. В урожае первого года была констатировано негативное взаимодействие между As, Cd, Pb и содержанием золы. У образцов, взятых в апреле, было констатировано более высокое содержание тяжёлых металлов, чем в образцах, взятых в октябре. Время посева наиболее значительно влияло на содержание свинца в двукисточнике тростниковидном, а норма дополнительного удобрения N на объём кадмия и мышьяка. Была установлена высокая позитивная корреляция между Cd и Pb (n=16; r=0.89; p<0.001), а между Cd и As - позитивная средне выраженная корреляция (n=16; r=0.73; p<0.05). Норма дополнительного удобрения N в качестве существенного фактора появляется потому, что мышьяк, кадмий и свинец содержится во многих минеральных удобрениях и пестицидов. Оценивая возможность попадания кадмия в растения, необходимо принимать во внимание следующее: историю удобрения поля, содержание органических веществ в почве, вид ухода за полем, климатические условия и особенности почвы.