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WOOD ASH AS A COUNTERMEASURE TO REDUCE ^{137}Cs UPTAKE BY BLUEBERRY: ACHIEVEMENT OF EQUILIBRIUM IN SOIL-PLANT SYSTEM

As a result of the Chernobyl accident in 1986, a significant amount of radioactive material was released in the environment. Radioactive contamination spread throughout Europe. The depositions of radioactive cesium (^{137}Cs) were 15 PBq in Belarus, 13 PBq in Ukraine and 29 PBq in Russia: a further 27 PBq was deposited in other European countries (De Cort et al., 1998). In natural and semi-natural environments, including forest, even many years after deposition ^{137}Cs is mostly concentrated in the upper 0-10 or 0-15 cm soil layers being potentially available for root uptake over the next years. The relatively long period of physical decay and high bioavailability of ^{137}Cs in forest soil make it potentially dangerous for animals and humans which can feed by forest products. Many countermeasures have been developed and applied for arable soils, but forest ecosystems still remain poorly studied and countermeasures are not effective enough. New and effective methods should be investigated. One of the countermeasures to reduce uptake of radiocaesium by plants and fungi in forest ecosystems can be application of potassium fertilizers. Potassium is a chemical analogue of radiocaesium and, therefore, can compete with cesium when it enters the plant. Application of wood ash may be another alternative to counteract radiocaesium uptake by forest vegetation. Biofuel ashes have relatively high potassium content (3–6 %) and if there is an excess of plant-available potassium ions in the soil, the plants take up the potassium ions instead of cesium. The aim of this study was to investigate the effect of wood ash application (both contaminated and uncontaminated with ^{137}Cs) on ^{137}Cs transfer from soil to forest plants, particularly blueberry (*Vaccinium myrtillus* L.).

The experiment was performed in forest ecosystems of Bazar forestry, Zhytomyr region and began on April 2012. The ^{137}Cs deposition in this area is between 7 and10 Ci/km^2 (260–370 kBq/m^2). The experimental plots (200 m^2 each) were randomly designed within the area about 0,6 ha. There were 3 treatments: 1 – Control (no ash was applied), 2 – "clean" wooden ash (uncontaminated by ^{137}Cs ash denoted here as Ash), 3 – ^{137}Cs-contaminated wooden ash (about 17.2 kBq/kg, denoted here as Ash cont.) Each treatment had 4 replicates. Both "clean" (Ash) and "contaminated" (Ash cont.) ashes were spread by hand on the forest floor once on April 20th 2012 at a rate corresponding 100 kg/ha potassium. Wood ash with potassium content about 3 % was used for the experiment. Samples (leaves and annual shoots) of blueberry (*Vaccinium myrtillus* L.), were taken monthly from May 17 till September 21 from each plot. In the laboratory collected samples were air-dried, crushed, mixed thoroughly and placed into plastic containers for gamma spectrometric measurements. The soil samples were taken by using metal sampler with a diameter 57 mm and a length of the working section 150 mm. Measurements of ^{137}Cs activity concentration in samples of plants and soil were performed at radiological laboratories in University of Agricultural Sciences (Sweden) by using HPGe detectors and Zhytomyr State Technological University (Ukraine) by using NaI detector. Each sample was measured to achieve the error below 5% but not longer than 24 hours. The obtained results were processed using Windas and Microsoft Excel software. Transfer factor (TF) – coefficient of radiocaesium transfer from soil to blueberry plants calculated by formula 1:

$$TF = \frac{Am}{As} \qquad (1)$$

where Am – activity concentration of ^{137}Cs per unit dry weight of blueberries (Bq/kg); As – density of soil contamination by ^{137}Cs, (Bq/m^2).

Soil contamination density was calculated by formula 2:

$$As = h \cdot \rho \cdot Am \qquad (2)$$

where h – sampling depth, m; ρ – average soil density, kg/m^3; Am – activity concentration of ^{137}Cs per unit dry weight of soil (Bq/kg).

Our studies showed a gradual increase of TF on Control treatment during the growing season with a maximum mean value in June 12 about 0,023±0,009 (0,013–0,030). On July 16.there was slightly decreased of TF 0,011±0,007 with a range between 0,006–0,021 and remained almost unchanged until September 21 (0,011±0,006 with a range between 0,002–0,016) (Fig. 1). ^{137}Cs activity concentrations in blueberry plants grown on plots with contaminated ash (Ash cont.) were higher than in control. Relatively high TF values on these plots in the beginning of vegetation could be due to ash particles were deposited on above ground plant parts at the time of ash spreading on the soil surface. Meanwhile, the maximum values of ^{137}Cs TF in blueberry were observed on Ash cont. treatment on June 12. The average TF value was about 0,027±0,015 (0,016–0,044). There was a gradual decrease of ^{137}Cs TF values in the period from June till the end of vegetation. On September 21 the TF values for blueberry plants on the treatment with "contaminated" ash were at the level of values for the control plants (Fig. 1).

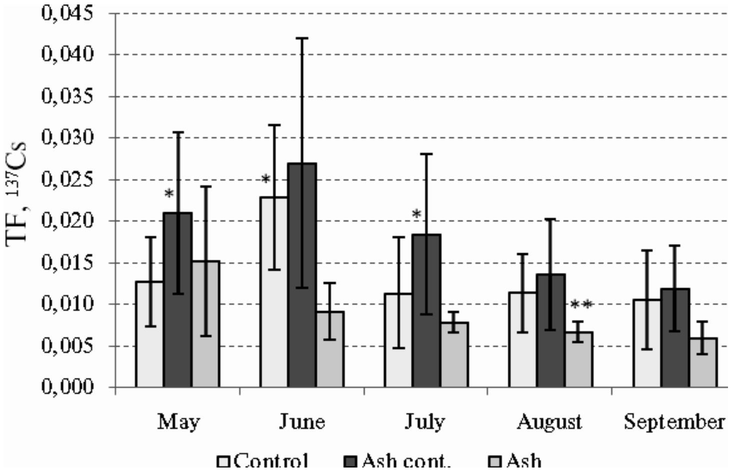

*Figure 1. ^{137}Cs TF values (n = 4) for blueberry (Vaccinium myrtillus L.) on treatments Control (no ash was applied), Ash cont. (^{137}Cs contaminated ash) and Ash (uncontaminated by ^{137}Cs ash) during the growing season in 2012: * - denote data obtained from 3 replicates; ** - denote data obtained from 2 replicates*

On the treatment with "clean" ash (Ash) TF of ^{137}Cs from soil to plants was higher only in the beginning of vegetation, namely 17th of May (mean 0,015±0,009 with a range 0,006–0,027), then there was an obvious trend to lower values of ^{137}Cs TF compared to Control. Thus, during June, July, August and September radiocaesium transfer factors from soil to plant blueberry on Ash treatment were significantly lower than on the Control treatment (Fig. 1).

The results obtained in this study clearly show that a single wood ash application of “uncontaminated” ash was able to reduce ^{137}Cs uptake by forest plants (leaves and annual shoots of blueberry) already during the first year. Transfer factors of ^{137}Cs from soil to studied plants appeared to be lower compared to that on control already in June, just about 2 months after ash application. Application of “contaminated” ash facilitated radiocaesium transfer to blueberries during the first months, compared to control plants; however this difference was less pronounced and disappeared at the end of vegetation period. At the end of vegetative the uptake of radiocaesium by plants grown on plots with “contaminated” ash was similar to that by plants grown on control plots whereas ^{137}Cs uptake by plants grown on plots with “uncontaminated” ash was distinctively (nearly 2 times) lower compared to both control and “contaminated” ash treatment. Thus, the equilibrium in forest soil-plant system after fertilization with “uncontaminated” ash is achieved already within one-two mouths, when fertilization with ash contaminated by ^{137}Cs seems to be require longer time – 4–5 month.

Based on the results of the first year of study it can be concluded that application of wood ash, both ^{137}Cs “contaminated” and “uncontaminated” in forest may be a feasible countermeasure to reduce radiocaesium uptake by forest plants: the effect seems to be achievable already within the first year after soil fertilization by wood ash.