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ORIGINAL PAPER

Influence of ^{137}Cs and ^{90}Sr on vegetative and generative organs of *Lepidium sativum* L. and *Tradescantia* clone 02

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Abstract The impact of ^{137}Cs and ^{90}Sr activity concentrations from 0.4 to 400 kBq·L^{-1} and from 1 to 200 kBq·L^{-1}, respectively, on seed germination of *Lepidium sativum* was insignificant; however, all concentrations of ^{137}Cs and 30 kBq·L^{-1} concentration of ^{90}Sr slightly stimulated root growth. The accumulated ^{137}Cs and ^{90}Sr stimulated shoot and parenchyma cell growth; ^{137}Cs suppressed RNA-polymerase II activity, and ^{90}Sr, on the contrary, stimulated it. Different genotoxic effects on *Tradescantia* clone 02 stamen hair cells were observed with comparable ^{137}Cs and ^{90}Sr activity concentrations. Activity concentrations of ^{137}Cs from 0.001 to 1.3 kBq·L^{-1} were more effective in *Tradescantia* clone 02 stamen hair cell reproduction, whereas the studied activity concentrations of ^{90}Sr (from 0.002 to 640 kBq·L^{-1}) induced more mutations.

Key words technogenic radionuclides • activity concentration • accumulation • *Tradescantia* clone BNL 02 • *Lepidium sativum* • RNA-polymerase II

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Introduction

Ionizing radiation can evoke various biological effects in plants, such as: inhibition or activation of DNA synthesis and synthesis of some metabolites, slackening or acceleration of cell division, growth suppression or stimulation, disturbance of ontogenesis phase dynamics, morphological changes of teratogenic origin, enhanced quantities of cells with increased numbers of chromosomal aberrations, increased number of individuals exhibiting chlorophyll mutations or new traits and reduced seed germination in progeny generations [11, 13, 18, 32, 35, 42]. It has been shown that in plants, radiocesium mostly accumulates (up to 25%) in the meristem (tissues where cells divide rapidly), which is relatively sensitive to ionizing radiation. Due to intensification of metabolic processes, large quantities of radionuclides can be accumulated in meristems, thus enhancing the internal irradiation doses [35, 37]. Radiostrontium mostly accumulates in plant tissues with dominating elongation growth and in those undergoing differentiation [18]. There are few papers dealing with plant response to the effect of incorporated ^{137}Cs [11]. Recently, only scarce studies on the impact of incorporated ^{137}Cs and ^{90}Sr on plants test-organisms have been performed [7, 8, 20, 23, 29].

Studies of the biological effects of the ionizing radiation of radionuclides are important for the assessment of radioecological condition of terrestrial and aquatic ecosystems in the surroundings of nuclear power stations, forecasting the ecotoxicological conse-

quences of radionuclides released to the environment during accidents and managing the issues of ecological standards on the presence of radionuclides in the environment. The International Radioecology Union (IRU) points out that in the 21st century special attention should be given to the investigation of the effects of low ionizing radiation doses caused to biota, especially those due to the incorporation of radionuclides into organisms [5].

The objective of this work was to determine and to compare the toxic impact of technogenic radionuclides, ^{137}Cs and ^{90}Sr, incorporated in plant into the meristematic cells of root and parenchyma cells of the shoots and the genotoxic impact on stamen hair cells, as well as to estimate the effect of ^{137}Cs and ^{90}Sr on the initial stages of protein synthesis in plant shoot cells.

Materials and methods

^{137}Cs and ^{90}Sr model systems

Hydroponics system for model experiments was prepared from ^{137}CsCl and $^{90}SrCl_2$ (Vsesojuznoe objedinenie "Izotop", Leningradskoe otdelenie, FSU). The ^{90}Sr isotope was in equilibrium with ^{90}Y. Initial 0.1 ml volume of each chloride was diluted 10^3–10^6 times or even more in order to obtain radionuclide activity concentration necessary for the study. In a separate variant of experimental series we used different radionuclide activity concentrations. Tests with *L. sativum* were carried out with ^{137}Cs (0.4, 4, 40, and 400 kBq·L^{-1}) and ^{90}Sr (1, 3, 30, and 200 kBq·L^{-1}) activity concentrations. The genotoxic studies of *Tradescantia* clone 02 were carried out at the following activity concentrations: ^{137}Cs, 0.001, 0.01, 0.13 and 1.3 kBq·L^{-1}, ^{90}Sr, 0.002, 0.02, 64 and 640 kBq·L^{-1}.

Test-organisms

Lepidium sativum L. Seed germination as well as root and shoot growth

The test was carried out following a modified Magone [24, 33] method. Briefly, 10 ml of lake water (as control) or a test aqueous solution of ^{137}Cs or ^{90}Sr was pipetted onto three layers of filter paper fitted into a 9-cm glass Petri dish. Twenty-five healthy looking *L. sativum* seeds of similar size were distributed evenly on the filter paper. The Petri dishes were placed in the darkness at 24 ± 1°C for 48 h. Afterwards, non-germinated seeds were counted, and root length was measured. The experimental set of each testing scheme involved 3 control dishes and 3 replications for each concentration activity of the radionuclides. The pH of lake water and test solutions with ^{137}Cs and ^{90}Sr was 7.5.

The level of toxic impact on *L. sativum* was assessed by the modified method of Wang [44]. According to the percent of root growth inhibition of 100–60%, 61–40%, 41–20% and lower than 19%, the toxic impact of the tested sample solutions on *L. sativum* was classified as very strong, strong, moderate and weak, respectively. The tested concentration was considered non-toxic if the biological parameter of *L. sativum* did not statistically differ from the control, and was considered extremely toxic if the seed did not germinate.

In experiments on the influence of ^{137}Cs and ^{90}Sr on plant shoot growth, *L. sativum* were grown in plastic boxes (110 × 160 × 6 mm) with covers to avoid evaporation. Each box contained 65 ml of water solution and 470 mg (~160) of seeds that were evenly distributed on a glass plate, covered with filter paper. The seeds germinated at 24 ± 1°C for 24 h in the darkness, and the shoots were grown for 6 days at continuous light at a temperature of 23 ± 1°C.

The morphological anatomical studies included all *L. sativum* shoots. We measured length of each shoot (with straightened leaves) and the weight of all the shoots. A microscope was used to determine the length, width and area of parenchymal cells.

Tradescantia. Somatic mutations of stamen hair cells

Experiments with *Tradescantia* (*Commelinaceae*) clone 02 were performed applying modified Mericle and Mericle [30] and Osipova and Shevchenko [36] methods. Four stems of cuttings bearing in fluorescence were immersed in 200-ml glass flasks containing 150 ml of lake water (as control) or test ^{137}Cs or ^{90}Sr aqueous solution. The flasks were exposed to the 16-h light/8-h dark cycle for 14 days. The radionuclide genotoxic impact on *Tradescantia* clone 02 was evaluated by the number of somatic (colourless) mutations and morphological anomalies in the stamen hair (SH) as well as by the amount of non-viable SH (their number indicates lethality when a hair contains less than 12 cells), which were counted using a light microscope. The number of non-viable SH reflects the ability of cells to divide. In each case, approximately 8000–11,200 stamen hairs were counted. The number of somatic mutations in the *Tradescantia* clone 02 stamen hair system in the control (lake water) was 0.62% ± 0.05%, whereas non-viable SH were not observed. The degree of ^{137}Cs and ^{90}Sr genotoxicity was evaluated according to the methods suggested by Marčiulionienė and co-authors [26]. A slight genotoxic effect on the *Tradescantia* clone 02 SH system is observed when the number of somatic mutations and morphologic anomalies do not exceed 1%, and ability of stamen hair cells to divide is 100% (e.g. no non-viable SH). The medium effect is observed when the number of somatic mutations and morphologic anomalies is between 1–4%, and ability of SH cells to divide reaches 60%. Strong genotoxic effect is characterized by the number of somatic mutations and morphologic anomalies exceeding 4%, and ability of SH cells to divide less than 60%.

RNA-polymerase II activity

Cell nuclei from the shoots of *Lepidium sativum* plants were isolated using the conventional methods [39] with modifications [31]. The isolated nuclei were incubated in a medium suitable to induce RNA-polymerase II activity [21, 41]. The incubation medium contained

triphosphates GTP, UTP, CTP (all disodium salt, Fluka Chemie AG, Switzerland) and ^{14}C-ATP (0.1 mM, spec. act. 3.1 MBq/g, Amersham Pharmacia Biotech, UK), Tris (Sigma-Aldrich Chemie GmbH, Steinheim, Germany)-HCl (P.A. Czech Republic) pH 7.6. The enzyme's activity was stopped after 40 min of incubation at +37°C by adding cooled trichloroacetic acid (final conc. 3%, Lach:Ner, Neratovice, Czech Republic). The residue was collected on membrane filters (∅ 2.5 μm; Pragopor, PRAGOCHEMA, Czech Republic) and washed with trichloroacetic acid and ethanol. A scintillation counter (Beckman LS 1801, USA) was used to measure the activity of incorporated ^{14}C-ATP. The Bradford method [4] was used to determine the protein content.

^{137}Cs and ^{90}Sr activity concentration measurements

^{137}Cs activity concentrations in the solution and in dry plant biomass were assessed by the method of gamma-spectral analysis. In order to assess ^{137}Cs activity in the solution, 3 ml of different activity solutions were placed in each of the vials of standard geometry. ^{137}Cs activity concentration in the small-volume samples was measured with a gamma spectrometer interfaced with a p-type high purity germanium (HPGe) detector (GWL-series), equipped with a well 40 mm deep and 16 mm in diameter, made by EG&G ORTEC. The relative efficiency of the detector was 17% (for ^{137}Cs 661.7 keV radiation). The measurement uncertainty did not exceed 6%, with a statistic error not larger than 1% [17].

^{90}Sr activity in the solution and plants was measured using a low background device UMF-1500 M (detector BT-13, registration efficiency 23% – 0.06 cps) (KIP, Tallinn, Estonia, FSU).

Statistical analysis

The data presented below are the arithmetical means of 2–3 experiments for which the standard errors of estimations were calculated. Standard errors did not exceed 5% for all data. A statistically significant difference between experimental and control samples was assessed by the t-test (at $p < 0.05$) using Statgraphics Plus Version 2.1 program (Statistical Graphics Corp., Herndon, USA).

Results and discussion

In reported laboratory experiments, the influence of variable ^{137}Cs and ^{90}Sr (prepared from $^{137}CsCl$ and $^{90}SrCl_2$) radioactivity concentrations upon the vegetative and generative organs of plants in the hydroponic medium was investigated.

Several experiments have been described concerning the effects of Cs^+ from CsCl on physiological processes in cress seedlings. Cesium (3–4 mM solutions) seems to disturb water uptake and tissue hydration in cress [9]; cesium concentrations of 2–4 mM also evoke osmotic stress in *Arabidopsis* [46]. Millimolar concentrations of cesium chloride induce a strong osmotic stress in the cress seedlings. This is evident from the decrease of water uptake and hydration of the tissues [43].

In the present study hydroponic medium was contaminated with ^{137}Cs and ^{90}Sr, which were prepared from 0.1 ml $^{137}CsCl$ and $^{90}SrCl_2$ by dilution 10^3–10^6 or more times. We assume, therefore, that non-radioactive cesium and strontium could not affect the studied *Lepidium sativum* and *Tradescantia* indices.

Investigation of the toxic impact of different ^{137}Cs activity concentrations (from 0.4 to 400 kBq·L^{-1}) on *L. sativum* seed germination and root growth revealed that after 2 days the seed germination did not statistically differ from the controls. However, this radionuclide slightly stimulated (11–12%) root growth (Fig. 1). Seed germination of *L. sativum* in the tested activity concentration (1–200 kBq·L^{-1}) of ^{90}Sr did not statistically differ from controls. However, ^{90}Sr activity in the range 1–30 kBq·L^{-1} after 2 days induced a statistically significant (8–12%) inhibition of root growth; the highest used ^{90}Sr activity concentration (200 kBq·L^{-1}),

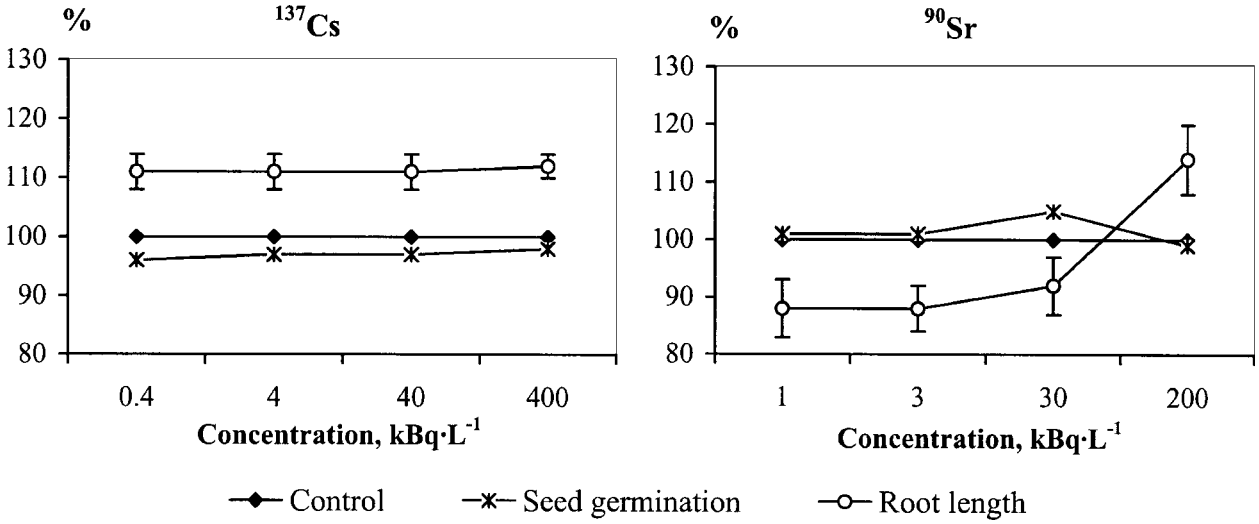

Fig. 1. Impact of incorporated ^{137}Cs and ^{90}Sr on seed germination and root growth of *Lepidium sativum* (after 2 days) depending on radionuclide activity concentration.

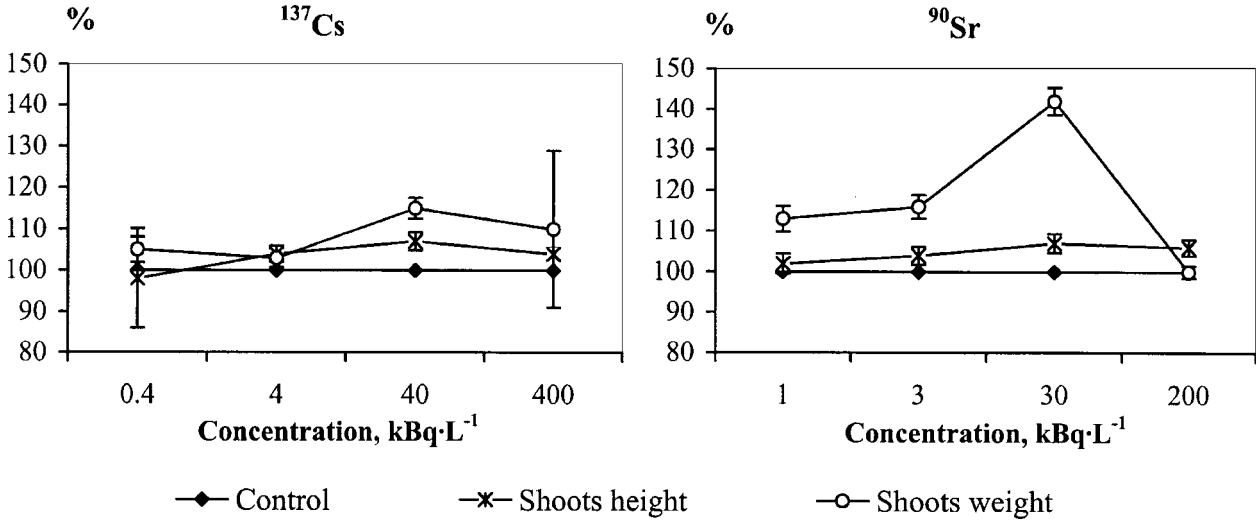

Fig. 2. Effect of ^{137}Cs and ^{90}Sr on shoot growth of *Lepidium sativum* (after 7 days) depending on radionuclide activity concentration.

on the contrary, stimulated the root growth (14%) as compared to control (Fig. 1). Analysis of ^{137}Cs effect on *L. sativum* shoot growth showed that after 7 days of exposure to the solution containing ^{137}Cs, shoot height and particularly weight had been stimulated only by the highest ^{137}Cs concentrations (Fig. 2). In many cases shoot parenchymal cell length and width stimulation was observed, which was most pronounced when ^{137}Cs activity concentration was 40 kBq·L^{-1} (Fig. 3).

Analysis of ^{90}Sr effect on *L. sativum* plant shoot growth revealed that after 7 days of exposure to ^{90}Sr solution, the stimulation of both shoot height and weight was most intensive at a ^{90}Sr activity concentration of 30 kBq·L^{-1} (Fig. 2). The same ^{90}Sr activity concentration stimulated shoot parenchymal cell length and width much more significantly than other studied concentrations (Fig. 3).

Out of numerous possible indices of cell functional state RNA-polymerase II activity was selected. It is directly connected with the process of RNA synthesis, and, therefore, it is informative of the primary stages of protein synthesis in the nucleus. RNA-polymerase II activity was controlled in a model of isolated nuclei in the RNA synthesis system by the amount of tracer ^{14}C-ATP which is dependent on α-amanitine (mRNA synthesis inhibitor) and in normal growth conditions correlates with cell growth intensity [10].

The model system of the isolated nuclei was formed of the nuclei isolated from cells of *L. sativum* shoots grown in a medium containing ^{137}Cs. All studied ^{137}Cs activity concentrations suppressed the RNA-polymerase II activity (Fig. 4). It was mostly pronounced at 400 kBq·L^{-1} ^{137}Cs activity concentration (by 66% less than in control). Recalculation of the obtained results for the number of shoots used in the test did not affect the trend observed for this radionuclide. Variable ^{90}Sr activity concentrations stimulated RNA-polymerase II activity of *L. sativum* shoots (Fig. 4).

It is known that tissues of plant generative organs are more sensitive to the impact of ionizing radiation than the tissues of vegetative organs [11, 38]. Cytogenetic effects are among the well-defined criteria for estimation of the impact of ionizing radiation upon biota [38]. The present investigation of the genotoxic

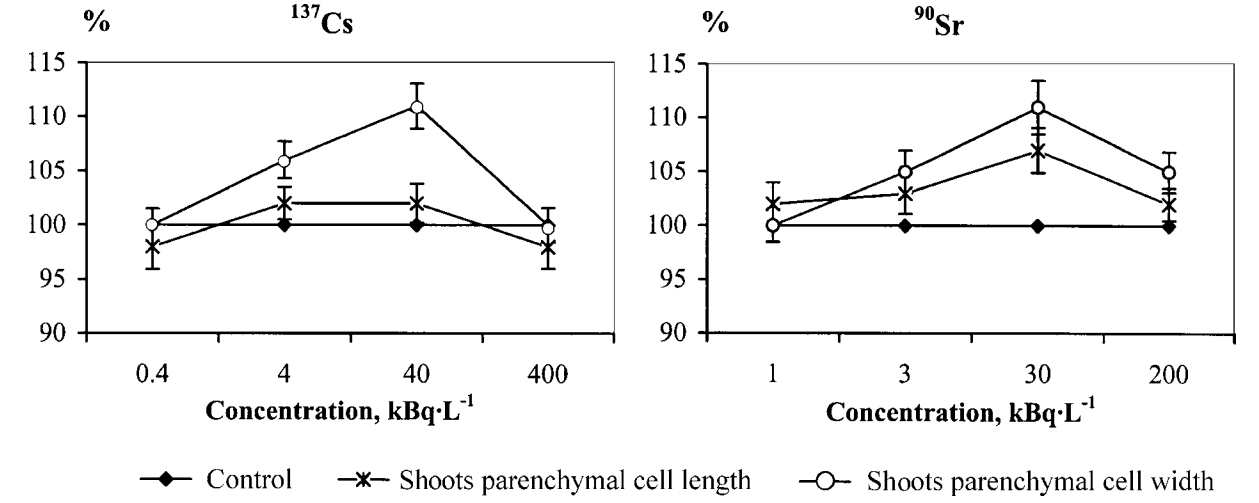

Fig. 3. Effect of ^{137}Cs and ^{90}Sr on parenchymal cell parameters of *Lepidium sativum* (after 7 days) depending on radionuclide activity concentration.

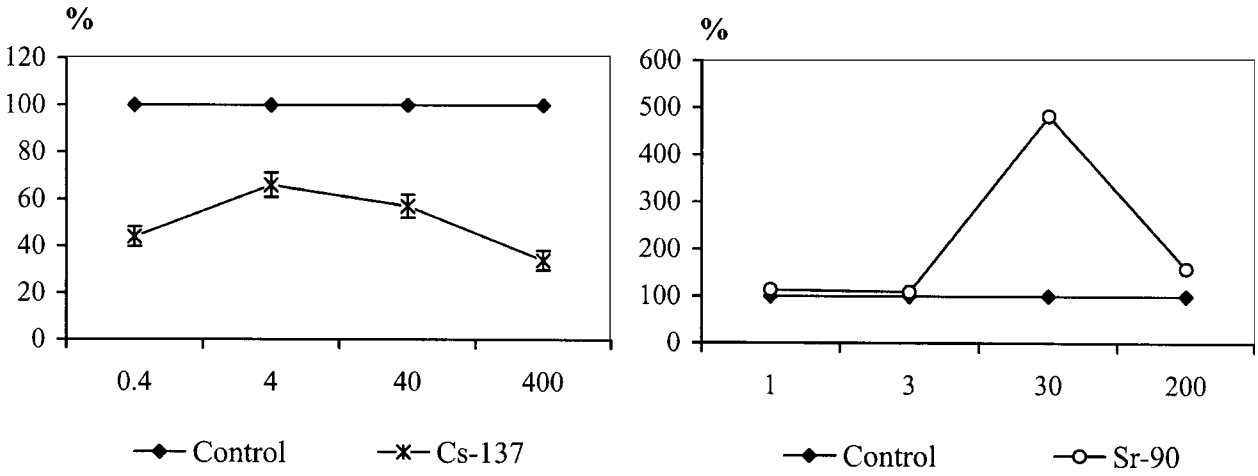

Fig. 4. Influence of ^{137}Cs and ^{90}Sr on the activity of RNA-polymerase II in the model RNA-synthesis system of nuclei isolated from *Lepidium sativum* cells depending on radionuclide activity concentration (standard errors did not exceed 5%).

impact of the radionuclides on *Tradescantia* clone 02 showed that on the 14th day of treatment the lowest activity concentration of ^{137}Cs caused 1.4% of somatic mutations and morphological anomalies and decreased the ability of cell division by 19%, while the effects of the lowest activity concentration of ^{90}Sr on these parameters were 1.8% and 28%, respectively (Fig. 5). The increase in the activity concentration of ^{137}Cs (from 0.001 to 1.3 kBq·L^{-1}) and ^{90}Sr (from 0.002 to 640 kBq·L^{-1}) caused a decrease in the cell division ability of stamen hair cells of *Tradescantia* clone 02, whereas the number of somatic mutations and morphological anomalies showed no significant change (Fig. 5).

The impact of comparable activity concentrations of ^{137}Cs and ^{90}Sr on the root growth of *L. sativum* was different. The root growth of *L. sativum* was slightly stimulated by all the studied activity concentrations of ^{137}Cs and only by 30 kBq·L^{-1} activity concentration of ^{90}Sr (Table 1, Fig. 1). Lower ^{90}Sr activity concentrations slightly inhibited the root growth. Thus, *L. sativum* root growth dependence on the studied activity concentration of ^{137}Cs and ^{90}Sr was observed, but for seed germination no such dependence was found. Shevchenko with co-authors [38] states that the alterations of meristematic tissues exposed to radiation are related to the morphological alterations of cells, and they can be important for the subsequent plant growth. The reasons for the difference of radiosensitivity of plant meristematic tissues may be linked to metabolism disturbances [11, 38].

^{137}Cs and ^{90}Sr treatment slightly increased shoot height and weight of *L. sativum* as well as parenchymal cell length and width (Table 1). The increase was mostly evident when the activity concentration of ^{137}Cs was 40 kBq·L^{-1} and that of ^{90}Sr – 30 kBq·L^{-1}; however, the stimulating effect of ^{90}Sr was much stronger than that of ^{137}Cs. At the activity concentration of ^{137}Cs, 400 kBq·L^{-1} and of ^{90}Sr, 200 kBq·L^{-1}, the increase in shoot height and weight as well as in parenchymal cell length and width was much slighter, and these parameters did not statistically differ from the control (Table 1). Naidich [34] stated that the analysis of morphometric indices which characterize the viability of seedlings in the early stages of plant development

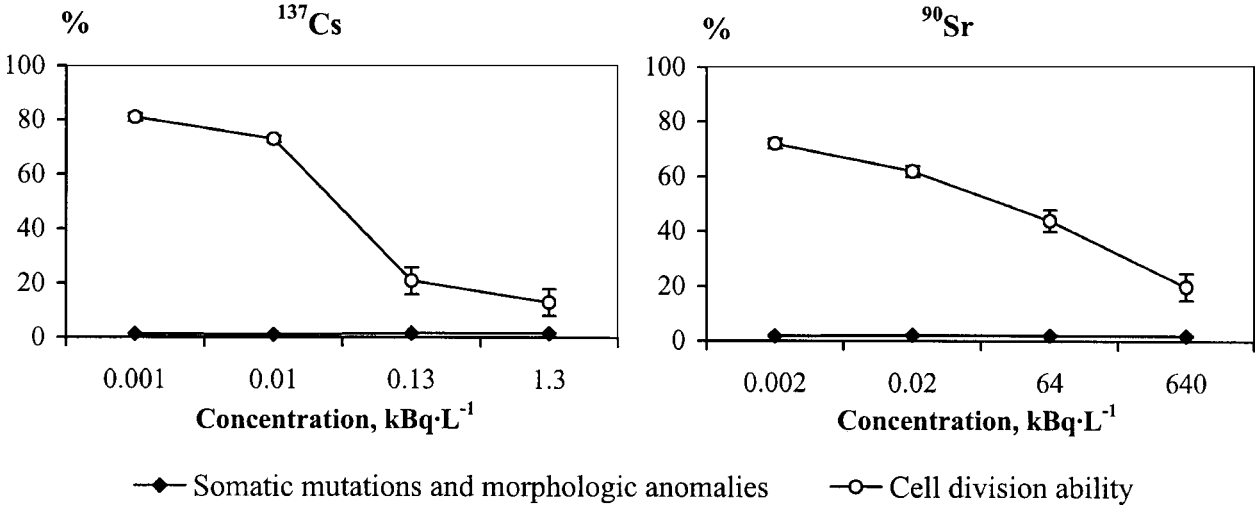

Fig. 5. Impact of ^{137}Cs and ^{90}Sr on *Tradescantia* clone 02 stamen hair cells (after 14 days) depending on radionuclide activity concentration.

Table 1. Effects of variable ^{137}Cs and ^{90}Sr activity concentration on *Lepidium sativum* L. and *Tradescantia* clone 02

Radio-nuclide	Radiation, energy, intensity	*Lepidium sativum* L.								*Tradescantia* clone 02 (after 14 days)	
		Initial activity concentration in aqueous solution [kBq·L^{-1}]	Roots (after 2 days)		Shoots (after 7 days)					Initial activity concentration in aqueous solution [kBq·L^{-1}]	Genotoxic effect
			Seed germination	Root length	Height	Weight	Parenchymal cell		Activity of RNA-poly-merase II		
							Length	Width			
^{137}Cs	β$^-$, 0.51 MeV, 92%	0.4	no effect	slight stimulation	no effect	no effect	no effect	no effect	strong inhibition	0.001	moderate
	β$^-$, 1.17 MeV, 8%	4	no effect	slight stimulation	no effect	no effect	no effect	slight stimulation	strong inhibition	0.01	strong
^{137m}Ba	γ$^-$, 0.661 MeV	40	no effect	slight stimulation	slight stimulation	slight stimulation	no effect	slight stimulation	strong inhibition	0.13	strong
		400	no effect	slight stimulation	no effect	slight stimulation	no effect	no effect	strong inhibition	1.3	strong
^{90}Sr	β$^-$, 0.535 MeV	1	no effect	slight inhibition	no effect	slight stimulation	no effect	no effect	slight stimulation	0.002	strong
^{90}Y	β$^-$, 2.24 MeV, ~100%	3	no effect	slight inhibition	no effect	slight stimulation	no effect	no effect	slight stimulation	0.02	strong
	γ$^-$, 1.75 MeV	30	no effect	slight inhibition	slight stimulation	strong stimulation	slight stimulation	slight stimulation	strong stimulation	64	strong
		200	no effect	slight stimulation	slight stimulation	no effect	no effect	no effect	moderate stimulation	640	strong

showed that stimulation of shoot growth by ionizing radiation was observed in parallel with enhanced cytogenetic damages. Consequently, the stimulation of plant growth cannot be considered as useful or at least not harmful response of plant to the impact of ionizing radiation.

^{137}Cs, at the activity concentrations of 0.4–400 kBq·L^{-1}, stimulated the growth of *L. sativum* root and shoots and suppressed RNA-polymerase II activity (Table 1). Growth reflects almost all processes that take place in the cell; therefore, for the elucidation of the toxic effects, the internal processes on which growth change is based are relevant. The effect of ^{137}Cs with respect to cells is stressogenic; therefore, it may influence the processes taking place in the cell nucleus. Studies on RNA-polymerase II activity in isolated nuclei showed that all tested ^{137}Cs activity concentrations (from 0.4 to 400 kBq·L^{-1}) inhibited the functioning of RNA-polymerase II. Although ^{137}Cs at test concentrations stimulated plant growth, it suppressed the initial process of protein synthesis, that is, transcription. The process of enhanced growth in plants can be caused by an enhanced functioning of the cell systems not related to the processes controlled by RNA-polymerase II, such as intensified water absorption, stock reserves of seeds and growing cells, etc.

The highest stimulation by ^{90}Sr of RNA-polymerase II activity as well as of the morphological and anatomical indices of shoot growth was observed at a 30 kBq·L^{-1} concentration of this radionuclide (Table 1). The obtained results correspond to the correlations of physiological processes in plants: under an enhanced activity of cell metabolism and nuclear processes, cell growth is accelerated and thus, the morphological and anatomical indices of shoot growth increase.

The stimulating effect of radionuclides can cause morphogenetic changes in plants manifested in early developmental stages [26, 30]. Morphological changes in plants were observed after the Chernobyl NPP accident in the 30 km exclusion zone around the NPP [14]. Plant morphological changes due to damaged reproductive organs can also decrease germination of ripe seeds. It has been found that toxicants at concentrations not exceeding the levels producing toxic effects can stimulate the plant metabolism as well as growth processes in plants and their cells [1, 7]. Nevertheless, the plant enzyme activity can be disturbed by metabolic products, and the degree of injuries depends on the intensity of metabolism [1, 6]. Geraskin with co-authors [12] noted that the storage and reprocessing of low and intermediate activity waste caused additional environmental contamination, which induced cytogenetic disturbances of both vegetative and reproductive organs in Scotch pine. In fact, exposure to ionizing radiation causes some alterations in plants populations such as chromosomal aberrations, visible mutations, biochemical mutations, changes in genetic structure of the population, extinction of sensitive species, and, at last, degradation of the ecosystem [38].

At comparable ^{137}Cs and ^{90}Sr activity concentrations, the genotoxic effect on *Tradescantia* stamen hair cells was different (Table 1, Fig. 5). ^{137}Cs at all studied activity concentrations (from 0.001 up to 1.3 kBq·L^{-1}) was more effective on *Tradescantia* stamen hair cell division, whereas ^{90}Sr at the concentrations from 0.002 to 640 kBq·L^{-1} induced more mutations (Table 1, Fig. 5). Similar results were obtained by other authors who studied radionuclide impact on test-organisms [22].

Different impact of the studied ^{137}Cs and ^{90}Sr activity concentrations on *L. sativum* root meristemic cells and shoot parenchyma cells, on the activity of RNA-polymerase II and on the *Tradescantia* SH system (Table 1) can be explained by different metabolism of these radionuclides in plant. The transport pathway and distribution of ^{137}Cs and ^{90}Sr in plants are different [3, 4, 11, 45] because their stable chemical analogs are macro elements K and Ca, respectively. The physiological similarities of Cs and K and Sr and Ca are frequently indicated in radioecological studies [3, 4, 45, 47]. The highest amounts of ^{90}Sr in the plant cell are localized in chloroplasts, while ^{137}Cs distributes evenly in cell protoplasm [15, 25]. Accumulation of ^{137}Cs in cell wall, depending on plant species, is from 2 to 7 times smaller than that of ^{90}Sr. However, the release of ^{137}Cs from cell wall to protoplasm is higher (10–20%) than that of ^{90}Sr (3–10%) [25]. The distribution of these radionuclides in organs and tissues of plant also is different [40]. ^{137}Cs in plants accumulates mostly in the zones of cell division and active metabolism (e.g., in plant meristem and young tissues) [11], whereas ^{90}Sr is mostly accumulated in plant tissues with dominating elongation growth and in the young tissues of stem and leaves [18]. ^{90}Sr activity concentration in the aboveground part of 7 species of plants from different biotopes (forest, grassland and wetland) was from 2 to 12 times higher than that in the underground part of these plants [16]. The distribution of ^{137}Cs activity concentration in the same plant species was different. The activity concentration of this radionuclide in some species was higher in the aboveground part of plant, while in other species it was higher in the underground part of plant [27]. Comparison of the ^{137}Cs activity concentration in *L. sativum* roots and aboveground part demonstrated that after 7 days ^{137}Cs activity concentration was 5 times higher in the roots than in the aboveground part of plant when *L. sativum* was cultivated hydroponically, and during the experiment the roots were incubated in lake water solution of 40 kBq·L^{-1} ^{137}Cs activity concentration [28]. Despite the similarity in chemical activity of Sr and alkaline metals, the effects of comparable activity concentration of ^{137}Cs and ^{90}Sr on the *L. sativum* root growth, shoot height and weight as well as parenchyma cell length and width, and RNA-polymerase II activity were different. The physiological similarity of cesium and potassium is frequently indicated in radioecological and physiological studies [11]. However, in the studies [11, 43] differences in cesium and potassium effects on some physiological parameters of *L. sativum* were determined. These distinctions could be due to the much higher atomic weight and ionic radius of cesium than those of potassium [11]. Basing on these statements, the influence of cesium on vegetative and generative organs of test-organisms should be stronger than that of strontium because of its higher atomic weight (133 against 87.6) and ionic radius (167 pm against 118 pm) [2, 19]. The summarized effects of variable ^{137}Cs

and ^{90}Sr activity concentrations on *L. sativum* and *Tradescantia* clone 02 (Table 1) did not show much stronger impact of ^{137}Cs as compared to ^{90}Sr. Such differences could be discussed considering different properties of these elements as radioisotopes. ^{90}Sr+^{90}Y β-radiation is significantly higher than ^{137}Cs β-radiation (Table 1) and emitted γ-rays of ^{137m}Ba are softer (0.061 MeV) than those occurring in the ^{90}Y decay scheme (1.75 MeV) [2]. It can be concluded that the observed ^{137}Cs and ^{90}Sr influence on the test-organisms corroborates our statement that ^{137}CsCl and $^{90}SrCl_2$ used in our experiments had no impact as stable cesium and strontium.

Conclusions

All the studied ^{137}Cs activity concentrations (0.4–400 kBq·L^{-1}) have been found to induce the slight stimulation of *L. sativum* root growth. Among all ^{90}Sr activity concentrations (1–200 kBq·L^{-1}) only the highest one increased *L. sativum* root growth. All other ^{90}Sr activity concentrations slightly inhibited root growth.

The highest ^{137}Cs activity concentrations (40–400 kBq·L^{-1}) slightly induced the shoot growth of *L. sativum*. ^{90}Sr also stimulated shoot growth, the stimulation being much more significant than in case of ^{137}Cs. All the studied ^{90}Sr activity concentrations slightly stimulated shoot growth, while 30 kBq·L^{-1} activity concentration of this radionuclide strongly stimulated *L. sativum* shoot growth.

All studied ^{137}Cs activity concentrations strongly suppressed RNA-polymerase II activity, whereas ^{90}Sr, particularly at a 30 kBq·L^{-1} activity concentration, strongly activated RNA-polymerase II.

All tested ^{137}Cs and ^{90}Sr activity concentrations caused a strong genotoxic effect in *Tradescantia* clone 02 stamen hair system. ^{137}Cs at all studied activity concentrations (from 0.001 up to 1.3 kBq·L^{-1}) affected to a greater extent all divisions in *Tradescantia* stamen hair, whereas ^{90}Sr at the concentrations from 0.002 to 640 kBq·L^{-1} induced more mutations.

Different effect of ^{137}Cs and ^{90}Sr on the growth of plant vegetative organs (roots and shoots), on RNA-polymerase II activity in RNA synthesis system of isolated plant cell nuclei and on the cells of a generative organ (flower) stamen hair cells can be explained by different metabolism of ^{137}Cs and ^{90}Sr, as stable chemical analogues of K and Ca, respectively, in the plant cells. This predetermines their variable accumulation in separate plant organs and their different distribution in plant cells and tissues.

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