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Influence of urea and of chlorocholine chloride on accumulation of ^{137}Cs in spring wheat crops*

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Abstract The influence of leaf feeding with nitrogen in urea solution and application of chlorocholine chloride (CCC) on the uptake of ^{137}Cs by spring wheat from the investigated soil samples and through leaves was studied in pot experiments. Spray application of nitrogenous fertilizer in urea solution with additional use of growth retardant were found to have brought about an increased accumulation in the grain of ^{137}Cs taken up by the plants from the contaminated soil. It was found that 2–4 times more ^{137}Cs accumulated in wheat grain from leaves contaminated in the flowering stage in comparison with that found in the grain of plants contaminated in the propagation stage. The application of leaf feeding with urea and chlorocholine exerted no influence on the accumulation of ^{137}Cs in grain if the plants had been contaminated superficially in their earlier development stages. Contamination with ^{137}Cs sprayed upon the plants after application of chlorocholine chloride appeared to pass to the spring wheat crops more readily.

Key words ^{137}Cs • leaf contaminated • radioactive pollution • soil contaminated • wheat

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Introduction

The Chernobyl catastrophe has caused radioactive pollution of soil in some areas to such an extent that its utilization without special treatments appeared impossible [3, 9]. Under such circumstances ameliorative ploughing for displacement of the polluted surface layer down to 60–70 cm depth seems to be the most effective way to decrease the accumulation of pollution in crops, to reduce the power of radioactive dose and to stop the spreading of further surface pollution [10]. However, this method could have been applied in practice only on limited, most polluted areas, first of all for economic reasons (high demand for mechanical power, poor efficiency). The effects achieved in the reduction of pollution appeared less effective than assumed on the grounds of scientific anticipation; precision in performance of such a ploughing was much lower than that under experimental conditions and part of the pollution was mixed with the arable layer of soil [7]. An effective way of limiting the uptake of radionuclides by crops from the contaminated soil appeared the application of mineral fertilization, particularly when the plants evidently responded to it with increased yields [5]. Nevertheless, in many cases plants grown on soils polluted with ^{137}Cs were noticed to react with nitrogenous fertilization giving increased accumulation of the nuclide [9].

A newly developed technology of leaf feeding with urea solution in different concentrations depends on the plant species and its developmental stage [4]. The possibility to interfere in the development dynamics of some tissues in cereals through application of growth retardant (chlorocholine chloride – CCC), allowed to

Table 1. Accumulation of ^{137}Cs in grain and straw of spring wheat from contaminated soil (% in 1 g d.m. from a dose per pot $\times 10^{-5}$).

Treatment	Grain	Straw
1. Traditional fertilization	4.16	14.25
2. Traditional fertilization + CCC	4.24	19.79
3. Leaf feeding with N only	5.71	20.46
4. Leaf feeding with N only + CCC	10.6	31.52
LSD* ($\alpha = 0.05$)	2.98	12.70

*LSD - Least Significant Difference

expect promising results in an attempt to limit the accumulation of ^{137}Cs in cereal crops.

This research has aimed at determining the effect of leaf feeding with urea and of applied growth retardant on the accumulation of ^{137}Cs taken up from the soil and through leaves by spring wheat.

Materials and methods

Glasshouse experiments were carried out in Wagner pots containing 6 kg of soil. The pots were filled with a humus layer of brown soil with pH in KCl = 5.4, containing 0.8% C org., 5.8 g P, and 13.2 g K per 100 g of soil (acc. to Egner). The test plant was spring wheat variety "Opolska".

Scheme of experiments:

I. A. Soil contamination; B. Leaf contamination
II. N fertilization: 1. traditional fertilization; 2. traditional fertilization + CCC; 3. leaf feeding with N only; 4. leaf feeding with N only + CCC.

The experiments were carried out in a complete randomized design in four replications. Fertilization with macro- and microelements was applied according to the method commonly accepted for pot experiments [11]. Leaf feeding with nitrogen was performed by spraying with a 18% urea solution in the propagation stage (23 in Zadoc's scale) and with a 6% solution in the 2nd node stage (32 in Zadoc's scale). Growth retardant was applied in the form of spray in the shooting stage (32 in Zadoc's scale). Prior to filling into the pots, the soil was contaminated with 5 ml of $^{137}CsCl$ of 8 MBq activity and thoroughly mixed. Leaf contamination was applied by spraying the plants with 2 ml of $^{137}CsCl$ of 0.8 MBq activity in the final stage of propagation and in the flowering stage. The plants were harvested at their full maturity and mean samples for incineration and radioactivity measurements were selected after drying and disintegrating them. In order to obtain normal distribution, rough results have been transformed according to the following formula:

$$y = \arc \sin (x/)^{1/2}$$

Variance analysis and testing of the means were carried out on the ground of transformed results. The measurements were made with a single-channel counting system with the use of a scintillation counter NaI(Tl). Depending on the counting rate the time of measurement was matched so that the statistical error with the least radioactivity measured in the grain did not exceed 10%.

Results and discussion

Results obtained in the experiment with the ^{137}Cs polluted soil (Table 1) showed that the leaf application of nitrogen by spraying with the urea solution and the simultaneous use of chlorocholine chloride brought about an increased accumulation of the radionuclide in grain. With joint occurrence of both factors the rate of the radionuclide accumulation in straw is pointing out to an evident cumulation effect. It is hard to say if the significant effect of increased ^{137}Cs accumulation in crops under the influence of nitogenous fertilization [9] can be referred also to the leaf feeding with urea solution. It seems that some explanation of this questions can be obtained by studying the potential and flow of ions through the cell membranes [2].

Leaf contamination with ^{137}Cs (Table 2) gave about 200 to 2000 times higher accumulation of the radionuclide in the grain as compared with that from the contaminated soil. Particularly ready passing of surface pollutions to crops has been reported by other researchers, too [1]. Attention was paid to more ready uptake of ^{137}Cs from the contaminated soil splashing over the leaf surfaces during heavy rains.

In treatments with pollutants sprayed onto leaves in the flowering stage 2–4 times more ^{137}Cs accumulated in the grain as compared with those polluted in the propagation stage. This fact has been corroborated by other authors [8]. Such an effect is related, first of all, with much larger surface of leaves, development of conductive tissues and undilution of ^{137}Cs taken up through leaves [6].

Table 2. Accumulation of ^{137}Cs in grain and straw spring wheat from contaminated leaves in two developmental stages (% in 1 g d.m. mass from dose per pot).

Treatment	Grain		Straw	
	propagation	flowering	propagation	flowering
1. Traditional fertilization	0.0304	0.0781	0.1875	0.4503
2. Traditional fertilization + CCC	0.0282	0.1247	0.1410	0.4591
3. Leaf feeding with N only	0.0289	0.0542	0.1441	0.2649
4. Leaf feeding with N only + CCC	0.0245	0.0789	0.1576	0.3644
LSD ($\alpha = 0.05$)	0.02		0.162	

Table 3. ^{137}Cs in spring wheat grain in % as based on the radiocesium content in straw.

Treatment	Source of contaminations		
	Soil	Leaves	
		propagation	flowering
1. Traditional fertilization	32.3	21.2	22.6
2. Traditional fertilization + CCC	33.7	23.4	19.3
3. Leaf feeding with N only	28.7	20.2	30.3
4. Leaf feeding with N only + CCC	35.9	15.6	20.7

In treatment of plant leaves with ^{137}Cs in the propagation stage the application of urea solution and growth retardant exerted no proved influence on the accumulation of the nuclide in the grain. In treatment of the contaminated material in the flowering stage it was differently; the application of growth retardant stimulated the accumulation of ^{137}Cs in grain, while the leaf feeding with urea limited it. The application of both measures made the accumulation similar to that in the control treatment with traditional fertilization. Different accumulation of ^{137}Cs in the straw in respective treatments confirmed the positive effect of leaf feeding with urea on the limitation of the radionuclide passing from the leaf surfaces into the plants. The application of growth retardant did not limit the uptake of the radionuclide, but when applied together with the feeding urea through leaves it levelled the limiting influence of the latter on accumulation of ^{137}Cs.

The comparision of ^{137}Cs per cent content in grain in relation to its amounts found in straw (Table 3) showed more pollutions having been taken up from the soil. It may be supposed that some of the pollution sprayed on leaves was not included into the metabolic cycle, and hence its apparently less participation in contamination of grain.

Conclusions

1. The application of nitrogenous fertilization by spraying the urea solution onto leaves with the simultaneous use of growth retardant appeared favourable to the increased accumulation of ^{137}Cs in spring wheat grain from soil contaminated with the radionuclide.
2. Superficial contamination of wheat leaves with ^{137}Cs in the flowering stage resulted in 2–4 fold increase in accumulation of the radionuclide in grain as compared with its amount found in plants contaminated in the propagation stage.
3. When contamination of leaf surfaces with ^{137}Cs occurred in the early developmental stages (up to propagation) then leaf feeding with the urea solution and application of the growth retardant did not cause any changes in accumulation of the radionuclide in grain.
4. In the case of superficial contamination with ^{137}Cs after application of growth retardants in the later developmental stages the possibility of the increased content of ^{137}Cs in grain should be taken into consideration.

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