On the problem of crop management in the radioactive contaminated territories

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The effectiveness of both separate and combined application of lime, potassium and organic fertilisers in decreasing ^{137}Cs accumulation in crop yield after the ChNPP accident has been demonstrated in field experiments on soddy-podzolic sandy contaminated soil as a result of the ChNPP accident. It was revealed that the radiocaesium transfer to crop products can be controlled by selecting crop species with different radionuclide accumulation ability. The technology of tillage was found to reduce radionuclide concentration in the yield up to a factor of 2. The problems of optimization of cereal crop protection on contaminated areas are considered. The advisability of using the method of presowing seeds incrustation by biologically active substances has been shown which makes possible stabilization of the phytosanitary situation and thus reducing pesticide application. In this case the yield gain and minimization of radiocaesium transfer to products is achieved.

When radiation accidents occur accompanied by the release into the environment of radioactive substances and contamination of agricultural lands, the intake of radionuclides to agricultural products becomes an additional source of irradiation of man. The limitation of dose burdens from external irradiation involves considerable expense. In contrast limitation of internal exposure by changes in the intake of radionuclides by humans with locally produced food-stuffs is a more realistic way to reduce the overall dose burden [4].

Plant growing on radioactively contaminated territories implies the usage of a system of agrotechnical and agromeliorative techniques aimed at reducing radioactive uptake to plant products. At the same time, alteration of mineral fertilising rates or ways of soil treatment can cause the development of pathogen communities in farm crops [2], which requires, along with phytozoomonitoring, the devising of a system for plant protection that takes into account the need for a decrease in the technogenous burdens to the agrosphere.

The problems related to the organisation of agricultural production in the contaminated area are of crucial importance in the rehabilitation of these territories and in providing safe residence of the population [3].

1. The use of agrotechnical and agromeliorative measures in crop production to control the radioactive uptake to yield

The accumulation of ^{137}Cs, the key dose-forming radionuclide, in plant products depends on the soil-climatic conditions, biological peculiarities of plants and agricultural practice. The acidity neutralisation of soil solution on all soil types in the contaminated area reduces ^{137}Cs and ^{90}Sr accumulation in the yield of cereal crops and cereal have by a factor of 2-3.

In the practice of land use in all soil-climatic zones of Russia affected by the Chernobyl accident, preference was given to measures of which the implementation of which does not require considerable changes in crop cultivation technologies and radical alteration of crop rotations traditional for the given territory. On contaminated agricultural lands the role of crop rotations is increasingly reducing radionuclide soil to plant transfer and migration via the trophic chain: soil-plants-(fodder)-animals-animal products. Thus, ^{137}Cs content in the grain of winter rye cultivated after legume-oats mixture for green fodder is by a factor of 3 lower than in the yield of plants cultivated after lupine and seradella.

In field and fodder crop rotations on soddy-podzolic soils with low contents of humus and mineral nutrients crop alternation should be directed at replenishing the supplies of the organic matter. The application of organic fertilisers (manure, peat-manure compost at a concentration of 40-80 t/ha) and double rate of phosphorous and potassium fertilisers results in a 2-3-fold decrease in ^{137}Cs accumulation in the yield of cereal crops and potatoes. A significant reduction in radionuclide concentration in plant products is achieved by a combined application of potassium fertilisers and lime materials, especially on soils with low availability of exchangeable potassium and calcium. In grain-grass crop rotations, the application of increased rates of potassium fertilisers (2K) and liming reduce ^{137}Cs accumulation in yield 1.4-3 times. The maximum positive effect in limiting ^{137}Cs transfer to plant products is reported for crop cultivation on soddy-podzolic sandy soil with the application of $N_{90}P_{60}K_{120\text{-}180}$ and lime materials containing magnesium.

The application of high rates of nitrogenous fertilisers, especially at unbalanced N:P:K ratios in soils, degrades the quality of farm products since ^{137}Cs transfer to plants is noticeably increased.

The technology of soil treatment provides a means for reducing radionuclide concentration in plant products. The content of ^{137}Cs in barley and winter rye grain, potato tubers is practically the same for autumn ploughing with disk harrows and ploughing with full layer turnover. A deep boardless cultivation of soddy-podzolic sandy soil results in removing of about 17-20% of ^{137}Cs beyond the arable layer, thereby reducing by a factor of 2-2.3 the radionuclide transfer to the yield of barley, winter rye and potatoes (Table 1).

Table 1
^{137}Cs content in yield of farm crops on soddy-podzolic sandy soil, (Bq/kg of produce)/(kBq/m^2 of soil)

Treatment	Barley, grain	Winter rye, grain	Potatoes, tubers	Maize, green mass
Ploughing (20-22 cm)	0.057	0.051	0.075	0.030
Disking (8-10 cm)	0.050	0.049	0.067	0.032
Deep boardless cultivation (40-45 cm)	0.028	0.023	0.033	0.031
ÍÑÐ$_{0,95}$	0.004	0.004	0.007	0.004

The application of agromeliorants capable of non exchangeable sorption of radionuclides in soil decreases ^{137}Cs accumulation in grass yields 1.5-5 times compared to the control. This technique needs to be introduced for improving grass stands of fodder lands on peaty soils where, because of a low content of clay minerals which transform ^{137}Cs in not easily available for root uptake forms, the radionuclide accumulation in the yield of grasses is by a factor of 3-4 higher than on soddy-podzolic soils. The application of agroameliorants such as bentonite, vermiculite, polygorskite clay to soddy-podzolic soil reduces ^{137}Cs transfer to plants 1.2-3 times. One of the most effective ways, economically inexpensive, on arable and fodder contaminated lands is a selection of crop species and varieties with minimum accumulation of radionuclides. Under similar crop cultivation conditions in crop rotations, the differences in ^{137}Cs accumulation reach 30-40% depending on species. The studies into the influence of variety peculiarities on ^{137}Cs uptake to plants testify that these differences amount to 2.5-7 times.

2. Optimisation of plant protection

Optimisation of the protection of farm crops cultivated on contaminated lands by special technologies can be carried out through an increase in the effectiveness of the existing means and methods (by taking into account the assessment of the advisability of using chemicals or corrections in times of their application), as well as through the use of safe preparations that enhance agrocenoses resistance [5]. Among these preparations are complex compounds with a biological activity based on plant growth regulators capable of enhancing farm crop resistance to abiotic and biotic effects [1] and reducing radionuclide uptake to yield.

The development and introduction into use of the optimized methods for plant protection against harmful organisms on contaminated areas was based on data of the long-term experiments on agricultural lands of the Novozybkov district of the Russian Institute of Fertilisers (the Bryansk region, soil contamination density of 0.8±0.1 MBq/m^2 for ^{137}Cs).

We have identified about 20 species of harmful phytophages during the long-term study of species diversity of harmful phytophages on fields of cereal crops. Among the dominants usually were frit flies (primarily Oscinella frit), Arhididae (primarily Sitobion avenae and Ropalosiphum padi) and thrips. The numbers of pests rarely exceeded an economic threshold of harmfulness and didn't significantly differ from their spread in the preaccidental period. However, some differences were observed in the numbers and species composition of pests depending on the agricultural practice.

Persistent, year after year affections such as Fusarium, Helminthosporium and Rhizoctonia in large areas of agricultural land have been noted. If fungi, the most commonly encounted on the phyloplan of cereals (barley, oats, rye) are Drechslera teres, D. avenae, Rhynchosporium gramineum, Erysiphe graminis, Septoria avenae, Cladosporium herbarum. The development of the rest typical for the region diseases (rust, smut, black grain) didn't show stability and was episodic in nature. A special feature of the phytosanitary state in the region was an asymptomatic (latent) spread of infection. This is particularly typical for Fusarium and Helminthosporium sativum on cereal crops.

A certain effect on the development of phytopathogens was exerted by the levels of mineral nutrition: increased rates of fertilisers ($N_{90}P_{60}K_{90}Mg_{30}$; $N_{120}P_{60}K_{120}Mg_{40}$) contributed to a more intensive development of Pyrenophora graminea on barley plants. On fields without fertilising the development of the disease was 3-5 times lower by the end of the growing season than on treated fields.

The evaluation of the phytosanitary state of crop stands has predetermined the approaches to the organisation of plant protection. In an effort to stabilize the phytosanitary state, an ecologically safe method of seed incrustation by biologically active substances (plant growth regulators) was chosen along with the adopted in plant growing seed dressers. All plant growth regulators are substances with adaptogenic properties: ambiol - an antistress antioxidant having antimutagenous properties; jsassol, cresazyn - antistress chemicals which enhance resistance of cereal crops to unfavourable factors. Seed dressers racsile and baitane are complex systemic preparations for simultaneous plant protection against internal and external infection.

A presowing treatment of barley seeds produced no significant effect on the entomofauna state. At the same time it considerably retarded the development of the major diseases (Table 2). A severe infection of seeds by Fusarium nivale facilitated the development of rots (75-85%), however treatment with baitane cut the disease development more than twice, and treatment with jsassol - by a factor of 4. A presowing incrustation of barley seeds also inhibited to some or other extent the penetration of microflora into the tillering node of plants and the application of growth regulators almost absolutely prevented the development of the net Perenophora teres and Ustilago nuda. A favourable phytosanitary situation in crop stands did not assume planned pesticide treatments during the growing period,

thereby decreasing the anthropogenic burden to the stuff involved in the technological processes.

Table 2
Influence of the presowing treatment of seeds on the development of barley diseases (%) and yield

Treatment	Fusarium Bipolaris	Fusarium spp.	Drechslera teres	Yield, cut/ha	KH (for grain)×10^{-3}
Control	75-85	66-74	12-17	18.5-19.0	10.0-10.3
Baitane	22-32	15-18	2-5	19.0-23.3	9.1-10.4
Racsile	20-25	10-13	5-6	19.5-23.0	9.0-10.3
Ambiol * + Baitane	15-26	0-3	1-2	22.4-23.8	8.0-8.2
Jsassol + Baitane	19-24	3-5	0-2	23.0-25.6	8.3-8.5

* - for cresazyn similar results were obtained.

The use of growth regulators for the presowing incrustation of seeds increased barley productivity and reduced by 20% the accumulation of radiocaesium, which is essential for plant production in contaminated areas.

Conclusion

The results from the investigations carried out in 1987-1995 indicate that factors such as soil biochemical processes, countermeasure implementation in the agroindustrial production and radioactive decay are responsible for ^{137}Cs reduction in plant products.

The application of agroameliorants shows the unexchangeable sorption of radionuclides in soil results in the 1.5 to 3 fold decrease in ^{137}Cs accumulation in yield, whereas regular application of physiologically acid mineral fertilisers on soddy-podzolic and peaty soils increases ^{137}Cs uptake by plants. The application of nitrogenous fertilisers in the ammoniac form also increases ^{137}Cs content in plant products. On arable lands these need to be applied at the N:P:K ratio of 1:1.5:2 under the projected yield with taking into account the biological peculiarities of plants and actual content of mineral nutrients in soil. The application of double rates of K and P fertilisers on soils low in available mobile K and P (as low as 10 mg/100 g soil) results in the 1.2-2.2 fold decrease in radionuclide accumulation in the yield of farm crops. The maximum effect (2.5-3-fold) in reducing ^{137}Cs uptake by farm plants on soddy-podzolic and peaty soils results from the application of lime, manure (more than 40 t/ha), double rates of K and P fertilisers). Of special importance in obtaining plant products with minimum radionuclide content are biological peculiarities of plants: an appropriate selection of crop species and varieties can 1.5 to 7 times restrict ^{137}Cs transfer to yield.

Ways of soil treatment such as deep boardless ploughing reduce concentration of radionuclides in the arable layer due to their redistribution and removal into the underlying horizons; ^{137}Cs content in the yield of farm crops falls 1.2-2 times compared to the conventional ploughing depending on the biological peculiarities of plants.

To optimize actions for crop protection on contaminated areas it is advisable to make use of a presowing incrustation of seeds by biologically active substances which allow one to stabilize the phytosanitary situation and to obtain sustained yields. This method contributes to the obtaining of "clean" plant products and reduces the probability of extra technogenous burdens to agrocenoses and man because of a decreased application of pesticides.

References

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