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Monograph "Eniology, Ecology and Diversity" About Ecological Disaster

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ABSTRACT

The monograph summarizes our studies on the enzyme-mycological depletion of cereal seeds in the contaminated zone of the Chernobyl nuclear power plant. April 26, 2024, marked the 38th anniversary of the Chernobyl nuclear power plant accident. In the contaminated zone (Novozybkovsky District, Bryansk Region), field experiments were initiated to study the accumulation of radiocaesium in the grain of 42 varieties of winter rye and 92 varieties of winter wheat. From 1987 to 1993, a total of 1,532 varieties from 28 crops of the global gene pool were examined. The research was conducted by the Moscow branch of VIR, in collaboration with several other research institutions. The findings of these experiments revealed that the global plant gene pool exhibits substantial diversity in radionuclide accumulation. The maximum variation in cesium-137 accumulation in grain under the same year and field conditions can be as much as 170-fold between different crops and up to ninefold among varieties within a single crop. The enological approaches described by I.M. Molchan, which consider informational and energetic interactions at various biological levels, should be integrated into both breeding programs and the assessment of the global plant gene pool.

Keywords: *Eniology, Ecology, Variety, Radionuclides, Cesium-137, Gene pool*

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INTRODUCTION

April 26, 2024, marks the 38th anniversary of the Chernobyl nuclear accident. Due to the scale of its consequences and the duration of its impact on the biosphere, the United Nations has called it the largest environmental catastrophe in world history (Belous, 2016; Anisimov *et al*., 2018; Orlov & Akanova, 2018; Fesenko *et al*., 2024). Thousands of people participated in the mitigation of the disaster's aftermath, including the former Moscow branch of the All-Russian Research Institute of Plant Industry named after N.I. Vavilov, which had a department of radiation genetics and radiobiology.

In 1987, Igor M. Molchan, the Head of the Department of Radiation Genetics and Radiobiology at the Moscow Institute of Radiation Research and Doctor of Biological Sciences was sent to Chernobyl. There, he collected ears of winter wheat varieties—Mironovskaya 808, Kiyanka, and Polesskaya 70—formed from the self-sowing of shattered grains from the 1986 harvest. This collection took place in the collective farms "Zavety Ilyicha" (Korogod village) and "Druzhba" (Zalesye village), located 10 to 15 kilometers from the Chernobyl nuclear power plant.

In the same year, in the exclusion zone for agro-industrial production, on the most contaminated field of the collective farm "Komsomolets" (village Babaki) in the Novozybkovsky district of the Bryansk region (with cesium-137 contamination density of 65.5 curies per square kilometer), field experiments were initiated to study the accumulation of radiocaesium in the grain of 42 varieties of winter rye and 92 varieties of winter wheat. From 1987 to 1993, a total of 1,532 varieties from 28 crops of the world gene pool were studied.

The scope of this research was made possible by the involvement of nearly all departments of the IGARD, whose staff not only prepared seeds but also participated in sowing, maintenance, and harvesting in the contaminated area. Due to the acute shortage of small-scale agricultural equipment, the IGADR management (Director A.D. Chovzhik) had to organize the transportation of a tractor, seeder, cultivator, loosener, and combine harvester to the contaminated area several times a year.

Many research institutions also participated in this work (preparation of seeds and their delivery to MOVIR, determination of radionuclides, analysis, and discussion of the data obtained): VNIPTI of Agricultural Chemicalization, VNII of Agricultural Radiology, Novozybkov Radiological Laboratory, VNII of Leguminous and Cereal Crops, NIISKh of the Central Regions of the Non-Black Earth Zone, VNII of Selection and Seed Production of Vegetable Crops, VNII of Fodder, Moscow and

Belarusian Agricultural Academies, Ukrainian and Belarusian Research Institutes of Agriculture, Kamenets-Podolsk Agricultural Institute, Gomel Agricultural Experimental Station, and others. Without their participation, it would have been impossible to carry out this work to such an extent. The assistance was mostly provided on a gratuitous basis.

Studies in the contaminated zone of the Chernobyl nuclear power plant have shown that the world plant gene pool has a great diversity of forms in terms of radionuclide accumulation. The maximum difference in cesium-137 accumulation in grain (under the same year and field conditions) between different crops can be up to 170 times, while the difference between varieties within a single crop can be up to nine times (Fesenko *et al*., 2021).

Based on the analysis of the results and literature data, genetic and physiological systems of traits that ensure the production of environmentally safe products in zones of radioactive contamination have been outlined for the first time. Principles for creating a model of technogenically tolerant varieties have also been developed. It has been found that breeding for minimal accumulation of contaminants in the marketable part of the crop is intrinsically linked to breeding for complex, non-specific field tolerance to abiotic and biotic stress factors in the environment. Consequently, plastic varieties are more commonly found among those that exhibit low radiocesium accumulation.

The common notion that radiation only has harmful and destructive effects needs to be reevaluated. Low doses of ionizing radiation (such as the natural radioactive background and biological field) are fundamental to the origin, reproduction, and evolution of life, as well as to energy-information interactions, the unity and integrity of biological systems, and the formation and development of Eniology, wave genetics, and other fields (Molchan, 2007; Vorontsova, 2013).

A systematic approach to an organism implies looking for a complex of correlatively related and interacting traits, rather than focusing on individual outstanding traits (donors). This is what N.I. Vavilov referred to it as an "evolutionary trait" and E.N. Sinskaya described it as a "plant constitution" (Vavilov, 1964).

Focusing on maximizing the expression of a single trait often results in the degradation of other traits, leading to breeding failures. For instance, one-sided selection for high yield has produced varieties with high potential productivity but increased yield instability (Zhuchenko, 1994). Similarly, the use of ultrafast-resistant forms of winter wheat as donors did not solve the issue of winter hardiness in the crop (Kalinenko, 1995). The use of drought-resistant foreign varieties did not enhance drought resistance in new spring wheat varieties. Moreover, utilizing short-stemmed varieties as donors failed to develop non-lodging winter wheat varieties (Sandukhadze, 1993). Hyproli, which was widely advertised as a source of very high lysine content in barley, did not achieve the expected breeding results.

The conclusion regarding the importance of harmony also applies to the interactions of organisms within the biocoenosis system (Balonov *et al.*, 2018). The creation of highly disease-resistant varieties through breeding often promotes the emergence and selection of more aggressive pathogen races, which can lead to the demise of crops of such linear varieties that do not integrate well into the surrounding biocenosis. Wild plants are almost always affected by parasites, and the pursuit of obtaining entirely unaffected plants is a human goal. In the biocoenosis system, the focus should be on tolerance rather than resistance, as this represents the most important natural direction of research in plant breeding and protection.

The need for harmonious information-energy interaction between a variety and its environment extends to both bio-geocentric and biosphere-cosmic levels. Breeding efforts aimed at creating varieties that are effective only with high doses of mineral fertilizers under intensive agricultural technologies contribute to the degradation of soil organic matter and its pollution. Therefore, breeding as a science objectively contributes to the impending ecological crisis.

The biosphere-cosmic principles of breeding, as discussed in the book by Igor Molchan, advocate for the creation of varieties that are not just agrochemicals efficient, but also cosmically efficient. This involves identifying samples that maximize the utilization of energy not only from the soil and the sun (photosynthesis) but also from other celestial bodies (cosmosynthesis). The future of humanity, and thus of breeding, is linked with autotrophy, as described by Vladimir I. Vernadsky. The soil is polluted with herbicides, pesticides, heavy metals, retardants, and radionuclides. Autotrophic varieties have the potential to ensure the ecological purity of agricultural products.

The materials in the book have been validated through the author's presentations at various scientific conferences, as well as in periodical scientific publications and textbooks. The book will be useful to enologists, ecologists, geneticists, breeders, seed growers, and specialists engaged in the development and implementation of environmentally safe technologies in polluted areas. It may also interest the general reader, especially if attention is paid to the poems and excerpts from other literary sources (approximately three hundred are included in the book) related to various scientific topics. It is impossible to conceal falsehoods in harmonious, natural rhyme (Molchan, 2007).

The monograph summarizes our studies on the enzyme-mycological depletion of cereal seeds in the contaminated zone of the Chernobyl nuclear power plant.

MATERIALS AND METHODS

In the contaminated zone of the Bryansk region, from 1988 to 1992, a total of 215 winter wheat varieties were studied, including 77 in 1988, 38 in 1989, 55 in 1990, and 45 in 1992. The varieties originated from different regions of our country and the world, including Moscow, Ivanovo, Rostov, and Voronezh regions, as well as Krasnodar, Altai, Krasnoyarsk, Primorsky Krai, Ukraine, Belarus, Poland, Germany, Finland, Sweden, and others. The vegetation conditions in 1989 and 1990 were favorable for the growth and development of winter wheat **(Table 1)**. Studies on enzyme-mycosis depletion of seeds were conducted using original methods (Temirbekova, 1998).

Table 1. Hydrothermal conditions of the growing season in the years of research.

Month	Temperature (°C)						
	Multi-year	1988	1989	1990	1991	1992	1993
March	-2.2	0.8	4.1	5.2	-0.5	2.9	-0.1
April	6.4	8.0	9.9	9.4	8.7	6.8	8.1

May	14.5	16.2	15.8	14.0	13.2	14.4	17.0
June	17.8	19.1	20.8	16.6	19.5	19.4	16.2
July	19.3	22.7	19.6	17.9	20.9	21.2	17.7
August	18.2	18.0	19.7	18.1	19.2	22.7	16.9
September	12.9	13.5	14.4	11.0	13.9	13.2	10.4
Precipitation, mm							
March	29.4	57.5	44.9	33.6	8.9	38.8	29.6
April	38.5	12.6	35.8	83.8	17.6	16.9	54.8
May	49.6	56.2	68.5	71.0	106.3	27.6	42.1
June	67.3	155.0	96.4	131.9	89.0	81.9	96.3
July	80.1	29.7	60.0	97.8	37.7	36.3	160.2
August	70.1	118.9	43.6	23.6	41.9	15.6	36.8
September	52.1	60.6	27.6	103.5	35.5	42.0	111.2

RESULTS AND DISCUSSION

Agrometeorological factors of the year play a significant role in the intake of radiocaesium into wheat grain. The differences in cesium-137 activity in wheat grain between the maximum (1988) and minimum (1990) values (nCi/kg) were observed as follows: Kolos 80 variety - 3.4 times, Donskaya bezostaya - 4.9 times, Mironovskaya 808 - 5.4 times, Kurgan 52 - 7.3 times, Yantarnaya 50 - 8.2 times.

Our data, along with that of other researchers, indicate that inter-varietal differences in the levels of radionuclide contamination of wheat grain within a single year are approximately equal to the differences in the accumulation of radiocaesium by a single variety across different years (Kharkevich *et al*., 2016; Kalinichev & Romanenko, 2020; Komissarova *et al*., 2022; Romanenko & Levkina, 2022).

The calculation of the correlation coefficient between radiocaesium activity and grain yield across different years (1988, 1989, 1990, and 1992) showed an inverse relationship between these indicators (R = -0.8 to -0.26). When grain yield decreases in dry years, the concentration of radionuclides in the marketable part of the crop increases. However, the study of the relationship between cesium-137 activity and yield of different varieties within the same year did not reveal a consistent pattern; correlation coefficients in 1988, 1989, 1990, and 1992 were 0.16 - 0.31 and 0.01 - 0.43, respectively.

In studying the relationship between cesium-137 activity in grain and air temperature, a direct correlation was found. The correlation coefficients between the content of radiocaesium in grain and the average monthly air temperature during the growing season (May-August) from 1988 to 1992 varied depending on the variety, ranging from 0.49 to 0.86. The highest values of correlation coefficients (0.71 to 0.99) were found in July when wheat grain formation and filling occurred. This indicates that higher temperatures in July 1988 (22.7 °C) and 1992 (23.2 °C) compared to 1989 (19.6 °C) and 1990 (17.9 °C) contributed to an increase in radiocaesium levels.

The significance of the period of wheat grain formation on cesium-137 intake was also evident in precipitation. Lower precipitation levels in July 1988 (29.7 mm) and 1992 (36.5 mm), compared to 1989 (64.0 mm) and 1990 (97.8 mm), favored an increase in radiocaesium in wheat grain. During this critical period for wheat grain yield formation, an inverse correlation between cesium-137 activity in grain and total atmospheric precipitation was observed (R = -0.79 to -0.98).

No such clear relationship was found between the content of radiocaesium in wheat grain and the total atmospheric precipitation for May and August as there was for July. The correlation coefficients between these indicators during the growing season varied among different varieties, from 0.34 to 1.0. Thus, when examining the relationship between the amount of precipitation during the growing season and the accumulation of radiocaesium in grain, not accounting for variety differences could lead to opposite conclusions about the presence of direct (variety Zarya) or inverse (Odessa 51) correlations about wheat. This data, along with conclusions from other researchers, indicates that when studying the influence of major agrometeorological factors on radiocaesium intake into plants, it is important to consider temperature and precipitation not only for the entire growing season but also at specific stages of ontogenesis (Roerich & Moiseev, 1989; Diakité *et al.,* 2024).

Increased accumulation of radiocaesium with decreased wheat yield under drought conditions is a metabolic response of weakened plants to anthropogenic influences (Sadykov, 1991). Under water deficit, growth processes are suppressed, protein metabolism is disrupted, and proteolytic enzyme activity is intensified, leading to a sharp decline in metabolic processes in the grain, resulting in poor yield. In conditions of moisture deficiency, there is an increase in the absorption and accumulation of both potassium and cesium in the plant, faster drying of leaves, accompanied by mobilization and outflow of nutrients into the grain, as well as an increase in the harvest index (Lukin & Mokrousova, 1991; Suchy, 2024). Unfavorable drought conditions contribute to the increased accumulation of radiocaesium in wheat plants and grain.

Based on the above data, it can be concluded that drought tolerance is a necessary prerequisite for the realization of a variety's genetic potential for radionuclide accumulation in plant products. In varieties that are not drought-tolerant, wet and dry years can lead to ambiguity in the expression of genetic traits due to the redefinition of the genetic formula of the studied quantitative trait (Belopolsky, 2020; Lastovetskyi *et al.,* 2024). This mechanism is one of the reasons for the inconsistency in the ranking of varieties in terms of radionuclide accumulation across different years. For example, the non-drought-tolerant variety Gama (Poland) in 1989 and 1990, years favorable for winter wheat cultivation, contained a small amount of radiocaesium in the grain, 0.44 and 0.2 nCi/kg, respectively, and ranked among the top varieties with minimal radionuclide accumulation (ranks No. 4 and No. 1, respectively). However, in unfavorable years 1988 and 1992, under conditions of decreased yield, the amount of radionuclide in the Gama variety increased significantly to 2.15 and 2.40 nCi/kg, respectively, placing it among the varieties with average (1988 - rank No. 29) and even maximum (1992 - No. 42.5) radionuclide accumulation.

The trait "radiocaesium activity" in grain is determined by radiocaesium resistance genes under favorable conditions for wheat development, while under drought conditions, it is determined by drought tolerance genes (Belopolsky, 2020). The drought-tolerant variety Donskaya awnless consistently ranked among the varieties with minimal radionuclide accumulation throughout all four years of study. Varieties such as Odesskaya 95, Zaliv, Rostovchanka, and Odesskaya 51 also exhibited low radiocaesium activity and were noted for their increased drought tolerance.

Key characteristics of drought-resistant winter wheat varieties with low radiocaesium accumulation in grain include: a relatively high concentration of potassium in leaves, which helps discriminate against the radionuclide in favor of its chemical analogue during the reutilization of substances from vegetative mass into grain; a deep-penetrating root system, which facilitates the uptake of substances from lower soil layers that are less contaminated with radionuclides; and higher efficiency in the use of assimilated nutrient elements for organic matter formation, which helps dilute the radionuclide. Agrochemical-efficient varieties are also characterized by their ecological plasticity (Klimashevsky, 1991; Batyrshayev & Bogdevich, 2011).

Varieties with minimal radiocaesium accumulation, such as Donskaya bezostaya, Rostovchanka, and Odesskaya 51, are distinguished not only by consistently high yields over the years but also by their grain quality. This quality largely depends on their resistance to the complex pathological condition known as EMIS (enzyme-mycosis seed exhaustion), which leads to a decrease in vitreousness and grain filling, formation of microcracks in the seed coat, germination at the root, and intoxication (Dunin & Temirbekova, 1978; Temirbekova, 1998).

The hydrothermal conditions of 1988 in the contaminated zone, characterized by high temperatures and abundant precipitation during the period of generative organ formation and the initial stages of grain weevil development, were favorable for the development of EMIS. Subsequent drought conditions exacerbated its effects. Varieties such as Ibis (with high amylogram), Odesskaya 51, Donskaya bezostaya, and Rostovchanka, which showed low radiocaesium accumulation in grain, were noted for their resistance to EMIS (Dunin & Temirbekova, 1978; Temirbekova, 1998; Cissé *et al.*, 2024).

The variety Hildur, which is not resistant to EMIS (according to IGUIR data), was the leader in radiocaesium accumulation in grain among the studied wheat varieties in 1988. The weak resistance of this variety to EMIS, associated with an extended period of active metabolism (due to the lack of physiological dormancy and germination of grain at the root) and loss of dry matter, leads to an increased concentration of radiocaesium in the grain.

In the group of varieties (Sv. 01751, Sv. 01744, Helge, Hildur, Boeguian, Urozhaynaya) with the highest radiocaesium values, samples from Krasnoyarsk and Primorsky Krai, Belarus, the Netherlands, Sweden, and Norway predominated, while those with the lowest values came from Rostov Oblast, Ukraine, Germany, France, and Czechoslovakia.

Varieties with high radiocaesium accumulation are characterized by a long vegetation period, tall plant height, a high number of spikelets and grains per ear, but a lower weight of 1,000 grains. In contrast, varieties with low radiocaesium accumulation are characterized by a shorter growing season, drought resistance, plasticity, larger grain size, and resistance to EMIS.

In conditions of radioactive contamination, the issue of the combined effects of various chemical pollutants is particularly relevant (Orlov & Akanova, 2018). ion in plants and other pollutants is an important task for future research. However, some data obtained from various experiments suggest the possibility of such a connection. In particular, late maturity reduces resistance not only to radiocaesium but also to the hazardous heavy metal cadmium (Gamzikova *et al*., 1993).

Drought tolerance decreases the levels of cesium-137 and aluminum in the plant. Among coarse-grained wheat varieties, those with minimal radiocaesium accumulation and a combination of other high-quality grain characteristics are much more common.

CONCLUSION

Thus, the biosphere-cosmic principles of breeding discussed in the monograph suggest the development of varieties that are not just agrochemical efficient, but also cosmically efficient. This involves identifying samples that maximize the use of energy from not only the soil and the sun but also from other planets through processes such as cosmosynthesis or autotrophy.

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