THE COMMON REED SEEDS' VIABILITY FROM WATER-BODIES WITH DIFFERENT LEVELS OF RADIOACTIVE CONTAMINATION

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Abstract: The results of the common reed's seeds biological characteristics investigation in conditions of long-term ionizing radiation impact are represented. The highest total absorbed dose rate was calculated for the common reed in the most radionuclide contaminated water bodies of the Chernobyl accident exclusion zone. Dose relationships between viability indexes and abnormalities frequency of germs were indicated. High abnormalities percent and reduced viability indexes of common reed's seed progeny in water bodies with heightened level of radionuclide contamination were defined.

Key words: radionuclide contamination, common reed, total absorbed dose rate, viability indexes, germs abnormalities.

1. INTRODUCTION

Radioactive contamination of environment is a challenging problem nowadays. Ambiguity of radioecological situation in the world requires systematic and long-time monitoring of biological effects of ionizing radiation on living organisms including changes of the most radiosensitive characteristics, physiological and biochemical processes, ontogenesis abnormalities etc. [1, 2]. Chernobyl and Fukushima disasters are the heaviest nuclear accidents in the history. Aquatic-plant communities constitute an integral part of fresh-water ecosystems. Early ontogenesis is one of life-cycle periods, the most vulnerable to ionizing radiation exposure, therefore radiation effects on seeds germination and germs growth are important to be investigated. The results of studies may be valuable for prevention of negative consequences of ionizing radiation impact on fresh-water ecosystems. The above studies make some contribution to solving a problem of economic use of lands and water-bodies objects, contaminated as a result of Chernobyl disaster [3]. The goal of research is to investigate peculiarities of the common reed's response on long-term ionizing radiation impact by means of viability indexes and germination processes analysis.

2. MATERIALS AND METHODS

2.1. Object and methodologies of research

For assessment of long-term ionizing radiation impact, seeds of the common reed (*Phragmites australis* (Trin) Ex. Steud) of 2009 year of vegetation were sampled. The common reed is a widespread air-aquatic plant which is either dominant or subdominant species among plant associations of aquatic ecosystem within the Chernobyl accident exclusion zone. Seeds of the common reed are ellipse-shaped grains of 1.0-1.5 mm length and 0.4-0.6 mm width. Color of seeds is brown-yellow or light-brown [4].

Viability, germination indexes of the common reed's seeds and abnormalities percent of the germs were investigated in conditions of laboratorial cultivating [5].

Our research was accompanied by methodology of internal absorbed dose rate assessment with dose conversion coefficients (DCC) using [6]. External gamma irradiation dose rate was measured by DKS-01 dosimeter and by Na-I field radiometer SRP-68-03. Correlation analysis was carried out according to [7, 8].

Seeds of the common reed were taken from water bodies with different levels of radioactive contamination. Common reed's seeds were sampled from polygon water bodies of the left-bank floodplain of Prypiat River – Glyboke and Daleke lakes; and right-bank floodplain – Azbuchyn Lake, weakly flowing Yanivsky Creek and Cooling Pond of the Chernobyl NPP within the Chernobyl accident exclusion zone. For comparison seeds were sampled from water bodies with background level of radioactive contamination – Kyiv water reservoir near Lyutizh village and Verbne Lake, located within Obolon residential district of the Kyiv City.

2.2. Viability indexes and abnormalities investigation

The process of generative reproduction of plants is one of the most radiosensitive ontogenesis periods [5]. Seeds are convenient object for investigation of radiation exposure effects on reproductive ability of higher plants. Laboratorial cultivating of seeds is an effective testing system for assessment of their survivability, indication of abnormalities, and higher plants' abilities to resist different additional effects [5]. Common reed's seeds for cultivation were planted on wet filtering paper in the Petri dishes. Seeds germinated in conditions of 5-10 kLk and 20-24 ^{0}C. Duration of experiment was one month.

Three viability indexes were investigated: technical germinating ability, germinating power of seeds and survivability of germs.

Technical germinating ability was calculated as the percent of germinated seeds.

Germinating power was defined as the percent of germs appeared at one third of the experiment period.

Survivability of germs was assessed as the percent of survived germs.

Speed of leafs and roots growth is an important indicator for assessment of ontogenesis damage. It was determined as the change of average length of roots and leafs per day.

Different groups of germs abnormalities were investigated. Specific group of them is so called chlorophyll or pigment abnormalities. Germs often have such abnormalities as "curled" hypocotile, roots, leaves or whole body, to the extent disturbance of normal geotropism [5]. Another frequent type of abnormalities is necroses of the roots and cotyledons of germs. Growth abnormalities are ones of significant group. They were defined as summary number of germs with more than one root growing from the common base, number of germs with roots growing from different points and number of germs without root.

Abnormalities number was defined as the total percent of germs with abnormalities of different types.

3. RESULTS

3.1. Total absorbed dose rate

Total absorbed dose rate (table 1) in the most radionuclide contaminated Glyboke and Daleke lakes was calculated as significantly higher than one in other water bodies.

Table 1. Total absorbed dose rate intervals in water bodies with different levels of radionuclide contamination.

Water body	Absorbed dose rate from radionuclides in different sources, μGy hour^{-1}		Radiation background, μGy hour^{-1}		Total absorbed dose rate, μGy hour^{-1}		Total absorbed dose rate, cGy year^{-1}	
	in water	incorporated radionuclides	min	max	min	max	min	max
Glyboke Lake	0.06	0.28	4.37	17.46	4.70	17.79	4.12	15.59
Daleke Lake	0.04	0.24	4.91	5.71	5.18	5.98	4.54	5.24
Azbuchyn Lake	0.02	0.13	0.55	1.37	0.70	1.52	0.61	1.33
Yanivsky Creek	0.01	0.02	0.38	0.71	0.40	0.73	0.35	0.64
Cooling Pond of the Chernobyl NPP	0.002	0.17	0.14	0.16	0.13	0.12	0.27	0.45
Kyiv reservoir	0.0002	0.02	0.17	0.22	0.20	0.24	0.17	0.21
Verbne Lake	0.00001	0.001	0.06	0.12	0.06	0.12	0.05	0.11

Total absorbed dose rate for the common reed varied in following ranges: 4.1-15.6 cGy year^{-1} and 4.5-5.2 cGy year^{-1} – in Glyboke and Daleke Lakes correspondingly, 0.6-1.3 cGy year^{-1}, 0.4-0.6 cGy year^{-1} and 0.3-0.5 cGy year^{-1} – in Azbuchyn Lake, Yanivsky Creek and Cooling Pond of the Chernobyl NPP correspondingly. The lowest absorbed dose rate was calculated for plants from Kyiv reservoir near Lyutizh village and Verbne Lake – 0.17-0.21 cGy $year^{-1}$ and 0.05-0.11 cGy $year^{-1}$ – correspondingly.

3.2. Viability and germination indexes

In conditions of the common reed's seeds laboratorial cultivation, enormous delay of the last germ appearance and low vitality indexes were indicated in more radionuclide contaminated water bodies of Chernobyl accident exclusion zone (table 2).

Table 2. Viability indexes of the common reed's seed progeny of 2009 vegetation year at different levels of radionuclide contamination of water bodies.

Water body	Total absorbed dose rate (cGy $year^{-1}$)		Period of germs appearance, day		Technical germinating ability	Germinating power, %	Survivability, %
	Min	Max	first	last			
Glyboke Lake	4.12	15.59	2	26	60.00±5.43	30.67±3.22	38.00±3.14
Daleke Lake	4.54	5.24	2	26	59.33±4.56	49.33±4.91	35.33±4.68
Azbuchyn Lake	0.61	1.33	2	26	66.67±6.82	46.67±4.23	42.00±4.18
Yanivsky Creek	0.35	0.64	2	19	55.33±4.92	46.00±3.22	36.67±3.21
Cooling Pond of Chernobyl NPP	0.27	0.45	2	19	72.67±5.12	57.33±5.43	55.33±5.31
Kyiv reservoir	0.17	0.21	2	9	83.33±7.31	86.67±6.25	48.00±4.37
Verbne Lake	0.05	0.11	2	9	92.67± 7.64	91.33±8.82	54.00±4.82

First germ appeared at second day of experiment in all water bodies. Enormously extended period between the first and last germs appearance – up to 19-th and 26-th day, was indicated for germs in more contaminated water bodies (Glyboke, Daleke and Azbuchyn lakes). Germs from Yanivsky Creek and Cooling Pond of the Chernobyl NPP stopped to germinate earlier – at 19-th day. In Kyiv Reservoir and Verbne Lake seeds germinated in the shortest period – from 2-nd to 9-th day.

Normal indexes of viability – technical germinating ability, germinating power and survivability were registered in water bodies with background level of radionuclide contamination – Kyiv Reservoir – 83, 87 and 48 % correspondingly and Verbne Lake – 93, 91 and 54 % correspondingly. However, investigated indexes were significantly lower in the polygon water bodies – Glyboke Lake (60, 31 and 38 % correspondingly), Daleke Lake (59, 49 and 35 % correspondingly), Azbuchyn Lake (67, 47 and 42 % correspondingly), Yanivsky Creek (55, 46 and 37 % correspondingly) and Cooling Pond of the Chernobyl NPP (73, 57 and 55 % correspondingly).

Inverse dose dependence of viability indexes – technical germinating ability, germinating power and survivability was registered.

Negative correlation between total absorbed dose rate and indexes of technical germinating ability (r = -0,637), germinating power (r = -0,833) and survivability (-0,639) was indicated.

Results of leafs and roots growth speed investigation (fig. 1) testify about growth speed differences in water bodies with background and heightened levels of radionuclide contamination.

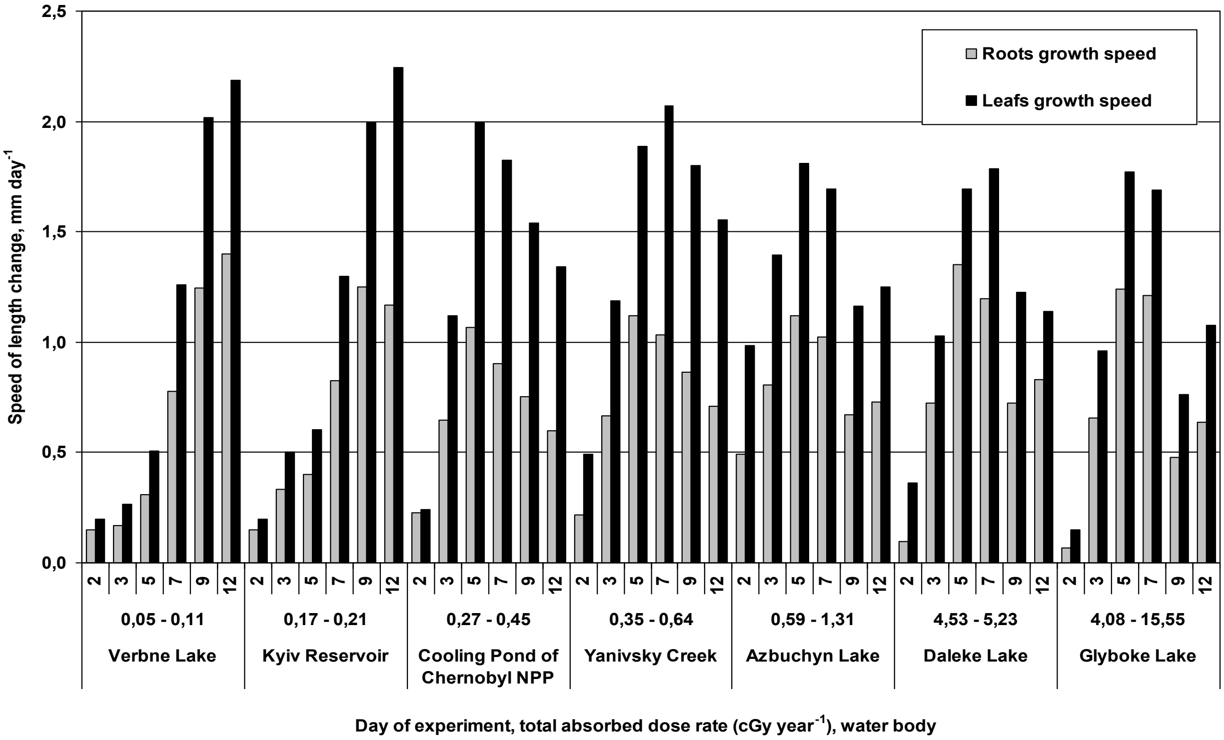

Fig. 1. Roots and leafs growth rate in water bodies with different levels of radionuclide contamination.

Rapid increase of leafs and roots growth speed in water bodies with background level of radionuclide contamination – Verbne Lake (0.2-1.4 and 0.2-2.2 mm day^{-1} correspondingly) and Kyiv Reservoir – 0.2-1.3 and 0.2-2.3 mm day^{-1} correspondingly, was registered during first twelve days of experiment. In polygon water bodies speed of both roots and leaf growth significantly differed. The highest speed of roots growth was registered in all polygon water bodies only at fifth day (1.1-1.4 mm day^{-1}). After fifth day roots growth descent was registered – up to 0.6-0.8 mm day^{-1}. In polygon water bodies leaf grew with the highest speed at 5-7 day of experiment (1.7-2.1 mm day^{-1}). After significant increase, leaf growth speed lowered up to 0.8-1.6 mm day^{-1}.

3.3. Abnormalities

Abnormalities of different groups were investigated. Only few works explain the real character of chlorophyllic abnormalities: they may be reasoned by gene mutation or chromosome aberration, they also can be inherited or somatic [9].

Geotropism disturbances are conditioned by different speed of division of initial cells, constituting damaged organ. They can be also reasoned by stretching, connected with genetically reasoned processes of the morphogenesis regulation [5].

Necroses of the roots and cotyledons of germs, are also genetically conditioned. It was approved that necroses of roots of Arabidopsis' germs appear as a result of mutations of certain genes [10]. In other work [11] it was noted that formation of cotyledons necroses was connected with mutation, resulted from insertion of certain DNA fragment.

Growth abnormalities – number of germs with ontogenesis disturbances: germs with more than one root growing from the common base, number of germs with roots growing from different points and number of germs without root were investigated.

High percent of germs abnormalities of different groups in the most radioactive contaminated water bodies of Chernobyl accident exclusion zone was indicated (fig. 2).

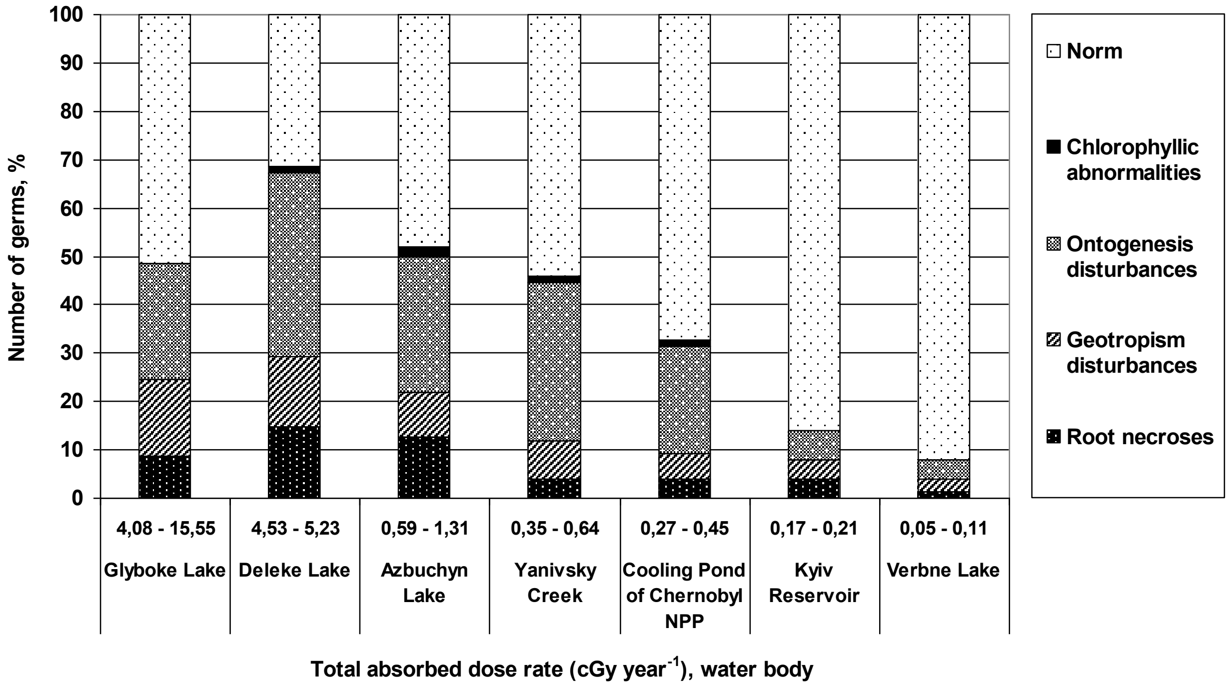

Fig. 2. Abnormalities of the common reed's germs in water bodies with different levels of radionuclide contamination.

Chlorophyllic abnormalities are the least frequent disturbances. Small number of the common reed germs (5 %) with nonchlorophyllic leafs was identified in water bodies.

The greatest number of germs with geotropism disturbances was registered in samples from the most radionuclide contaminated polygon water bodies – Glyboke (16 %) and Daleke (15 %) lakes. In water bodies with background level of radionuclide contamination number of geotropism disturbances was not greater than 4 %.

Maximal number of root necroses was defined in Glyboke, Daleke and Azbuchyn Lakes – 9, 15 and 13 % correspondingly. Significantly lower number of root necroses was determined in germs from Yanivsky Creek, Cooling Pond of the Chernobyl NPP and Kyiv Reservoir – about 4 %, and the least one – in Verbne Lake – 1%.

Considerably different number of ontogenesis disturbances was defined in polygon water bodies and water bodies with background level of radionuclide contamination. In polygon water bodies it varied from 38 % (Daleke Lake) up to 22 % (Cooling Pond of the Chernobyl NPP). In water bodies with background level of radionuclide contamination total part of these abnormalities was not higher than 6 % (Kyiv Reservoir).

Thus, high total percent of germs abnormalities in the most radioactive contaminated water bodies of Chernobyl accident exclusion zone (69, 52 and 49 % – Daleke, Azbuchyn and Glyboke Lakes correspondingly) relatively to water bodies with background level of radionuclide contamination (14, 8 % – Kyiv Reservoir and Verbne Lake correspondingly) was determined. Correlation dependence between different average absorbed dose rate and root necroses ($r = 0.535$), ontogenesis disturbances ($r = 0.532$) and geotropism disturbances ($r = 0.907$) was calculated.

4. CONCLUSIONS

The total absorbed dose rate for the common reed in the most contaminated water bodies of the Chernobyl accident exclusion zone was in range 4.1-15.6 cGy year^{-1}, in water bodies with background level of radionuclide contamination - 0.05-0.2 cGy year^{-1}.

Analysis of roots and leafs growth speed of the common reed's germs denotes significant disturbances during plants ontogenesis in water bodies where total absorbed dose rate varies in range 1-15 cGy/year^{-1}.

Low viability (31 %) and extremely high abnormalities percent (up to 70 %) of the common reed's germs were defined in more contaminated water bodies of the Prypiat River floodplain.

Correlation dependence (r=0.5-0.9) between total absorbed dose rate and abnormalities of germs development was determined.

The common reed is a wide-spread species in the reservoirs of different types, and also enough sensible and convenient object of radiation monitoring of aquatic ecosystems under impact of nuclear fuel cycle enterprises. This species can be used as one of the reference hydrobionts at development of fundamentals of the environment protection from ionising radiation with use of the standard based on non-human biota.

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