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Gamma-radiation effect on the parameters of the population recovery of plants

N.I. Ivanishvili*, M.E. Gogebashvili, N.Z. Gvritishvili

Radiation Safety Problems Laboratory of I. Beritashvili Center of Experimental Biomedicine, Gotua Str. 14, Tbilisi, 0160, Georgia

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ABSTRACT

Investigation of the effects of different physic-chemical factors on the ecosystems is one of the important scientific tasks. From this perspective, it is to be mentioned an effect of such a strong damaging factor as ionizing radiation. Radiation damage is reflected differently in relation to the levels of organization of living organisms. On the relatively early stage of radiation damage determination of post-irradiation regeneration indicators on population level gives possibility to forecast the sustainability of ecosystems. In order to determine the indicators of post-irradiation regeneration of plant populations we have used as a model water plant – Lemna minor L. During the exposure of radiation on different levels of organization differences are identified not only according to qualitative features but also by the character of direction of the development of the processes of postradiation regeneration. A conclusion is made that if during the acute radiation it is possible to determine radioresistance of certain plants, which is based on the plant potential to post-radiation regeneration, the investigation carried out through chronic irradiation gives the possibility to determine the indicators of the ability of the plant to adapt to the radiation.

1. Introduction

During the formation of radiobiological reactions, each level of the organization of the organism is characterized by specific mechanisms of postradiation recovery. It is known that, during the investigation at the cell level, the biomodels are represented by tradescantia. The processes of post-radiation recovery are studied on the basis of the use of roots apical meristem and tissue cultures, and on intact plant level, for the purpose of determining such phenomenon, the growth intensity rates and plants certain parts architectonics are studied [1,2]. If, in relation to the cells, tissues and organs we deal with realization of reparative, regenerative and other compensatory type mechanisms, in relation to cenoses population recovery rates are the leading criteria [2]. Naturally, according to the known post-radiation recovery mechanisms, the interaction of the above listed levels represents a radiobiological axiom. At the same time, the diversity of plant organisms and the unique structures in their organization allow to use them as testing systems during the study of restoration processes [3–8]. It is understood that a population level of plant organization is characterized by certain features. In this regard, the mathematical method of the calculation of the realization of the reproductive potential is to be noted, however the latter is based on the intensity of the recovery, which is proportional to the level of injury, does not take into account the dynamics of population recovery [3]. Therefore, the main objective of our research was the search of such plant objects for their use a biomodel, which would provide us with an opportunity to establish how radiation damage to a separate organism would realize itself at a population level.

2. Objectives and methods

The research took place on a representative of *Lemna* family - *Lemna minor L.*; among the flowering plants, *Lemneae* represent a unique example of an extreme reduction of the whole plant, they have a very simplified structure and a small size, therefore, there is a possibility to cultivate them in sterile conditions, they grow well on mineral nutrient mediums, are easily controlled and change according to the cultivation conditions [9–13].

We have cultivated *Lemna* on Steinberg nutrient medium in Petri dishes [14]. We have carried out irradiation with isotope ^{137}Cs 0,1–15 cGy (centigray) per hour dose interval, and researched

* Corresponding author.
E-mail address: nazikoivanishvili@gmail.com (N.I. Ivanishvili).
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postradiation regeneration specificity through the calculation method for reproductive potential realization. The method is based on the establishment of time (t) for doubling the quantity of population components, during the effect of damaging factor, which is calculated by coefficient (r) for the instant growth of population. The change of the latter value reflects the resistance of the environment, that is to say characterizes the sum of all the limiting factors of the environment that impede the realization (r maximum) of reproductive potential. After the exposure time passed, the total amount of the fronds is calculated on the control and each dose (including mother individuals and fronds separated from mother individuals). Based on the received results a population's instant growth coefficient (r) is calculated:

$$r = \ln(N_t) - \ln(N_o)/t,$$

where N_o is the total amount of the fronds; Nt-the final quantitative of the fronds; t-exposure time. Afterwards, for each t-quantitative doubling time (t doubl.) is calculated:

$$t_{doubl.} = \ln(2)/r = 0,6931/r$$

3. Results and analysis

The investigation was based on the *Lemna* biological features; in particular, on its vegetative propagation specifics, when fronds develop on one plant until certain extent, that is to say colonies form, and on the next stage decomposition of these colonies and separate organisms production is underway [15–17].

The first picture reflects the formation of radiobiological reaction at an organism level, which is analyzed on the basis of frond quantitative indicators dynamics. In the given dose interval (0–200 Gy) a clear dose regularity is noticed; in particular, on the 21st day of post-irradiation period, the number of fronds reached 142 in the controlled version, while in the version irradiated by 25 Gy this indicator did not exceed 106. Even more potent inhibition was observed at 50, 100, 200 Gy, the number of fronds therefore constituted 60, 52, 44. The dynamics of the growth of the number of fronds differed according to the versions; if in the controlled version, the curve had an exponential nature, in the irradiated versions, at the initial stage (during 6 days), inhibition of the mentioned indicators was noticed; in the days following post-irradiated period (6–21 days), also differences between doses were observed; namely, if, during irradiation at 25 Gy, quantitative growth of fronds characterized for post-irradiation regeneration was observed, this characteristic was unchanged during irradiation at 50–200 Gy. Therefore, different levels of damage were revealed as well as different dynamics for the regeneration processes. Naturally, in order to solve the above task, the next stage of the investigation foresaw to explain in what extent it is possible to determine regeneration intensity of population through the model used by us via damage level for certain organisms' (see Fig. 1).

As it is seen from the picture 2, there is certain regularity in relation to the dynamics of the regeneration of population; in particular, 100 Gy is a dose which causes separation of fronds; here prevails plant quantity with two or one fronds, therefore the quantity of certain plants also rises: the quantity of the plants in the control is unchanged (10 plants were and stayed 10, however, on each plants the number of fronds has risen). In the version irradiated at 100 Gy 24 plants have developed (on the expense of plants with one and two fronds). A similar picture was observed in the version irradiated at 200 Gy – here plants with only one and two fronds were produced, the total amount of which reached 28 (the 3rd day). Afterwards, the range of plants having different number of fronds (within 1–6 fronds) has expanded and the quantitative indicators of certain plants have risen; in the control version 14 plants have developed; the version irradiated at 200 Gy is noteworthy, where the quantitative growth of the fronds was underway on the individuals with one frond on the expense of the development of the 2nd frond, so in the end, the ratio between plant individuals with one and two fronds changed, and the total amount of the plants stayed unchanged (28 plants) (see Fig. 2).

In order to study the parameters of the biomodel presented by us, the investigation was underway on two levels of chronic radiation exposure; in particular, 10 cGy per hour and 15 cGy per hour (Fig. 3). As one can see from the picture, in the conditions of irradiation at 10 cGy per hour, the curve reflecting time dynamics of the population number doubling is identical to the control (non-irradiated) version of the curve. As for the strong suppression of the dose, 15 cGy per hour according to this indicator it differs from the control version both quantitatively and qualitatively; namely, the parameter denoting the population quantity doubling time appears after the 9 day latent period passes, moreover, its numerical value is sharply increased (Fig. 3-A). This indicates that there is an actual nonreversible suppression of realization of reproductive potential that in our opinion may be used as a criterion for the dynamics of population viability and reproduction, during radiation exposure.

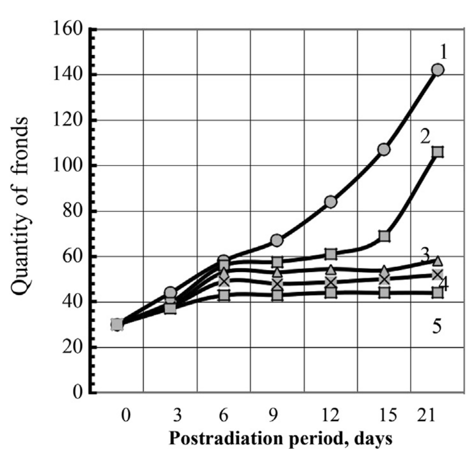

Fig. 1. Gamma-radiation effect on *Lemna* frond quantitative parameters. 1- Non-irradiated; 2- Irradiation at a dose of 25 Gy; 3- Irradiation at a dose of 50 Gy; 4- Irradiation at a dose of 100 Gy; 5- Irradiation at a dose of 200 Gy.

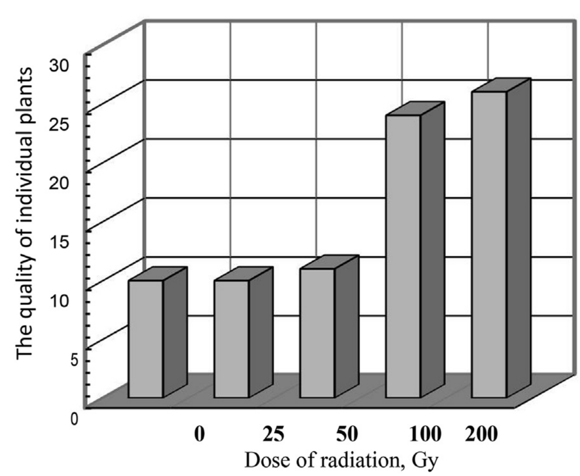

Fig. 2. Gamma-radiation effect on the intensity of *Lemna minor L.* population regeneration.

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