LABILIZING ACTING ATOMIC RADIATION ON PHOTOSYNTHETICAL APPARATUS (LAAR)

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In the connection with Chernobyl APS accident, arose the question about the transfer and accumulation of radionuclides in plants and the effect ionizing radiation on plant organism as the first link of biological food chain "water – soil – plants – animals – man". It is necessary to stress that the mechanism of effect of low, stimulating radiation doses on plant organism [1] and, especially, on photosynthetic apparatus is not sufficiently studied, and the experimental data on the role and significance of low doses are not definite [2].

In our studies with application of radionuclides, mainly – of carbon ^{14}C, the physiologic, biochemical and metabolic peculiarities of process of chlorophyll formation in plant organism were revealed. In particular, it was established that the turnover of ***a*** and ***b*** chlorophyll (Chl) took place even on late phases of ontogenesis, in absence of growth, indicating thus that this process is a characteristic feature of photosynthesizing apparatus [3, 4].

The temperature optimum (30 – 40^{0}C) and the light one (1000 – 10 000 luxes) of Chl ***a*** and ***b*** were found as well as a considerable resistance of this process to low (0^{0}C) and (50^{0}C) temperatures. This is the physiologic and biochemical basis of wide natural habitat of various species of plants on the Earth.

It was shown also that the formation and preservation of labile subfund of Chl ***a*** as predecessor is a factor of accelerated or slow transfer of ^{14}C from Chl ***a*** to Chl ***b***. Were obtained the evidences of existence of process of dark stabilization of easily extracted labile subfund of both Chl in absence of pigments decrease as well as of phenomenon of its repeated labilization at the pigments destruction in the darkness or in the old zones of normally illuminated leaves/ This testifies to the heterogeneity of chlorophyll`s labile form.

In the research with application of detergents and ultrasound, it was found a special high-labile form of Chl ***a*** and ***b*** that is very active in metabolism but not significant in termsof quantity and not fixed structurally yet. Oh the basis of another data, the conclusion was made that out of three labile chlorophyll forms–especially labile (ELCF), normally labile (NLCF) and repeatedly labilized (RLCF) – the NLCF is the most active in photosynthesis.

The data were obtained that testify to the high significance of protein synthesis in RNA for new formation of Chl in leaves with already formed photosynthetic apparatus, to the proceeding of Chl

turnover in mature chloroplasts by the origin of its molecules not only in new centers of biosynthesis but also within the limits of already existing centers, as well as to the stimulation of Chl ***b*** on the basis of repeatedly labilized Chl ***a*** and (or) by deblocking the polyenzyme complex of biosynthesis centers - Chl synthetase.

In studies of higher plants carried out after the Chernobyl NPS accident, a number of regularities in the effect of low doses of atomic radiation on the plant organism was revealed. In correspondence with developed in the Laboratory of Radiobiology of Plants concepts (V.I.Gaponenko, 1989) of probable correlative dependence between the metabolism (turnover) of Chl and the activity and productivity of photosynthetic apparatus under the influence of stimulating low radiation doses (2.5 – 5.0 Gy), were obtained data on the symbatation between the process of Chl formation (including 5-ALA, protochlorophyllide, Chl ***a*** and ***b***) and the photosynthetic activity – photochemical (Hill reaction) and fermentative, as well as the resistance in various species of plants growing in the conditions of high radiation background or grown from gamma-irradiated seeds (V.I.Gaponenko, L.K. Sukhover, N.V.Goncharova, V.P. Matsko, V.V.Shewedov, V.A. Kravchenko, N.V.Shamal, I.V.Zhebrakova et al.). In various species of plants – components of phytocoenoses of south-east of Belarus (PSRR) - not only photosynthesis intensified but also increased assimilation numbers (AN, mg of $^{14}C_2$/mg of Chl in an hour) [4].

However, in the extreme conditions, the affects of such doses on physiological and biochemical processes of plant organism appear as negative (impeding) ones.

The physiological and biochemical processes in rye, barley and clover grown from seeds irradiated in stimulating doses of 2.5, 5.0 Gy and others, were studied under the influence of extreme factors. The next was found in this study:

1. – increase of sensitivity of rye and barley to the moisture deficiency at seed germination (saccharose solution, osmotic pressure: 5-10 atmospheres);
2. – less significant activation of growth processes (length of sprouts, biomass) at the etiolation of irradiated rue plants as compared with control plants; these indices were stimulated with irradiation in the normal light conditions;
3. – at the lowered illumination (950 luxes) – absence of effect of stimulation by irradiation of biomass and Chl accumulation, speed of reaction of conversion of Chl ***a*** to Chl ***b,*** that takes place in barley sprouts at higher illumination (2 400 luxes);
4. – negative effects of seeds irradiation on its germination in the conditions of salinization (2,5 % solution of NaCl);
5. - decrease of heat resistance of sprouts of rye grown from irradiation seeds, by the criterion of damage of membrane structures of cells of Chl-bearing tissues at the temperatures as 30 - 60^0C (Table 1);
6. – stimulation of process of photosynthetic pigments accumulation and general productivity of plants of irradiated barley at the favorable soil moisture as compared with control plants and the decrease of this stimulation in the conditions of temporary soil drought (Table 2);
7. - decrease of phytomass of irradiated clover as compared with control plants in the field experiment in drought conditions (1995);

Table 1. Damage by high temperatures of Chlorophyll-bearing tissues in rye leaves of control and experimental variants (1 – First signs of browning; 2 – partial browning of leaves; 3 – total browning)
(The data of L.K. Sukhover and N.V.Shamal)

Variant	Degree of damage	% of leaf damage at the temperature (^{0}C)			
		30^0	40^0	50^0	60^0
Control	1	40±8	60±10	64±5	22±6
	2	---	4±3	23±6	38±6
	3	---	---	---	40±9
	Total	40	64	87	100
5.0 Gy	1	54±4	65±5	57±10	19±5
	2	---	14±8	28±7	35±6
	3	---	---	11±7	46±9
	Total	54	79	96	100

Table 2. Content of photosynthetic pigments and general production ability of barley plants of irradiated variant as compared with the control plants at the favorable soil moisture and in the conditions of temporary soil drought
(The data of L.K. Sukhover and N.V.Shamal)

Variant	Chl (***a***+***b***), mg/g	Carotinoid, mg/g	Vegetative weight, g/plot	Weight of seeds, g/plot	Weight of 1000 seeds, g
Control	1,38 ± 0,02	0,41 ± 0,01	31,9	18,4	47,1
Drought	3,66 ± 0,05	0,93 ± 0,01	15,7	5,46	25,3
5.0 Gy	1,49 ± 0,03	0,41 ± 0,01	34,0	21,6	53,9
5.0 Gy + Drought	1,18 ± 0,08	0,81 ± 0,01	16,5	6,11	27,7

8. – decrease by the preliminary irradiation in 0.5 Gy dose (growth stimulating) of the radioresistance of pea plants to the following irradiation in 8.0 Gy dose (much more significant in the variety with more intensive growth and crop yield) (Table 3);

Table 3. Change of the quantity of chromosome aberrations in mitotic cells of pea roots irradiated in 2-days age
(The data of V.V.Shewerdov and N.V.Goncharova)

Dose, Gy	Quantity of aberration for 100 cells	
	"Belorusskij –1" variety	"Bogatyr" variety
Control	1,20 ± 0,39	1,40 ± 0,32
0.5	2,37 ± 0,80	2,45 ± 0,79
8.0	10,46 ± 0,62*	13,31 ± 0,89
0.5 + 8.0	16,12 ± 0,86**	17,94 ± 0,98

* - the differences are reliable relating to preceding variants
** - the differences are reliable relating to 8.0 Gy variant (P< 0,05).

9. – removal of the stimulating effect of ions copper (as one of heavy metals) on the processes of growth of root system in pea plants (in germination stage) from the variants of γ-irradiation in 0.25 – 1.5 Gy doses; this effect was observed at lower doses (0.01 – 0.15 Gy).

The adduced above results correspond to the developed in the Laboratory hypothesis (V.I.Gaponenko [5]) about the labilizing acting of atomic radiation (LAAR) based on the weakening of protein-protein and lipid-protein interactions in membrane systems of plants [6, 7]. It is possible that the hereditary apparatus of call is also affected. We can suppose that the proper process of stimulation of (Chl formation) or other reactions in plants under the influence of radiation is carried out by the mechanisms of 3 types:

1. inmediate stimulation of formation of final and (or) intermediate products;
2. inhibition of factors that limit reactions (synthesis);
3. deblocking of process through the destruction of a pert of molecules of before formed product.

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