Biochemical Mechanisms of Plant Adaptation under Radiation Impact

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(Received February 6, 2008; revised April 14, 2008)

Abstract

Radiation impact on plants *Pentaphylloides fruticosa* (L.) O. Schwarz has been studied. It has been established, that the radiation factor pressure initiates adaptation processes affecting the growth and development of plants, as well as physiological and biochemical reorganization of the metabolic processes determining population existence in a habitat. It is experimentally demonstrated that the biosynthesis of the total content of flavonoids in *Pentaphylloides fruticosa* leaves is intensified under radiation impact. It is revealed that the content of flavonols (both total and in groups) in *P. fruticosa* leaves demonstrates a 2.3-fold increase as compared to the reference, and at the same time the difference against the reference increases with the increase in the contamination level. Individual flavonoid components have been shown to form different types of response to radiation influence in an organism. The content of hyperosyde, quercitrin and kaempferol decreases with the increase in radiation contamination, the content of other flavonoid components, on the contrary, increases. The qualitative flavonoid content in leaves of both irradiated and reference plants remains constant. Phenomena of leaf surface reduction, a lengthwise decrease in the annual spear and leafstalk gain, an increase in the number of leaves on a spear. It has been found that with the increase in irradiation the differences against the reference increased according to the majority of criteria. Different organs of *Pentaphylloides fruticosa* exhibit different accumulative ability with respect to radionuclides: the content of ^{90}Sr in leaves is higher compared to that in stems irrespective of the level of contamination, whereas for ^{137}Cs such a correlation is not observed.

Key words: radiation impact, adaptation of plants, flavonoids, morphological characteristics, *Pentaphylloides fruticosa*

INTRODUCTION

Nowadays a man-caused subjection of biota has become one of the most significant ecological factors. In this connection the estimation of adaptive potentialities of living organisms dwelling in radiation biocenoses finds a special urgency. Adaptation processes reflect the tendency of dynamic balance between the state of biological systems and changing life conditions [1]; in particular, with an ionizing radiation background. Certain margins of ionizing radiation adaptation standards are inherent in each species. The optimum level is determined by a natural ionizing radiation background.

During the adaptation processes coming to be, ontogenetic potentialities of an organism are used to a maximum extent, which poten-

tialities also restrict the spectrum of arising genetic changes [2]. The major responses of plants to the impact of a man-caused factor, *e.g.* radiation, include the changes in the processes of plant growth, development, reproduction and survival rate, as well as physiological and biochemical reorganization of metabolic processes determining the population existence in a habitat [3–5].

The analysis of data available from the literature indicates that numerous morphological characteristics are mainly used in order to study the changes occurring in a plant organism under unfavourable factors. Phenolic compounds, including flavonoids are used as biochemical attributes much more seldom. Meanwhile, flavonoids those representing the most widespread group of phenolic compounds are highly efficient natural adaptogens those play a significant role in the adaptation of plants with respect to various oxidizers [6–8].

The accumulation of these compounds in a plant as a response to the influence of unfavourable or unusual factors seems to be a mechanism for protecting the photosynthetic complex against extensive oxidation damage [9, 10]. Furthermore, the analysis of biochemical reactions of a plant with respect to certain man-caused or natural stresses and their comparative studies on these phenomena with a valid reference allow one to draw important conclusions concerning environmental conditions even in the absence of any external damage signs [7–9].

As a result of radiation accident at South Ural (the Mayak PA) in 1957 an East Ural radioactive trace (EURT) had been formed serving for 50 years running as a unique range for carrying out experimental work in the nature.

In order to study biological effect of low ionizing radiation dozes on plants we have chosen such a pant as Kuril tea (*Pentaphylloides fruticosa* (L.) O. Schwarz, Rosaceae family) as a model object. This plant represents a vastly branching bush up to 1.5 m in height with imparipinnate leaves and golden-yellow large flowers, aggregated usually on the tips of spears. This species is of widespread occurrence throughout East Siberia, the Far East, growing in Northern America and occasionally occurring in the Western Europe, Caucasus, Ural [11, 12].

According to [13–15], *P. fruticosa* produces a significant amount of flavonoids (from 2 to 14 %). It is just the fact that has determined the choice of this plant as an object for the studies. It is established that flavonoid-like compounds inherent in *P. fruticosa* are presented mainly by a group of flavonols. So, from the aerial part of *P. fruticosa* the authors have isolated and then identified such compounds as aglycons (quercetin, kaempferol and 7,3′,4′-tri-O-methylquercetin), not less than five flavonol glycosides (quercitrin, hyperoside, quercetin arabinopyranoside, isoquercitrin and astragalin) and the three acylated flavonol glycosides such as 6″-O-gallate-3-β-*D*-quercetin galactopyranoside, terniflorin and tribuloside [16–21].

The purpose of the present work consisted in revealing the changes of biochemical and morphological parameters of Kuril tea (*Pentaphylloides fruticosa* (L.) O. Schwarz) under the conditions of radiation impact.

EXPERIMENTAL

The subject of inquiry was presented by four-year-old *Pentaphylloides fruticosa* plants bedded as planting stock in 2004 in the head part of the EURT in two areas with different radionuclide contamination level (experiment) and in a background area outside the zone of contamination (reference). The planting stock was cultivated at the experimental introduction site of the Altai Division of the Central Siberian Botanical Garden, SB RAS, the Kamlak village using seed harvested in natural cenosis population in the neighbourhood of the Bichiktu-Bom village (the Central Altai, Onguday District).

The area No. 1 was located at the head part of the EURT, 6 km distant from the place where a vessel with radioactive waste products exploded in 1957, on the axis of the trace in the region old track road. The area is located within a vast clearing in a lighted birch forest of park type with a sparse adulteration of pine on grey woodland soil. The undergrowth is sparse, being mainly presented by dog-rose. The average density of contamination with ^{90}Sr amounted to 35–39 MBq/m^2, that for ^{137}Cs was at about 2.2–2.4 MBq/m^2, and the density of contamination with Pu was up to 96 MBq/m^2. The gamma background level on the surface

of soil was equal to (310±80) μR/h, the β-flux density on the surface of soil being as high as (2180±150) β-particles/(min · cm^2).

The area No. 2 was located at the southern lakeside of the Berdenish Lake within the territory of an evacuated village, on leached chernozem soils. The density of contamination with ^{90}Sr during the studies amounted to 15–20 MBq/m^2, that for ^{137}Cs was at 0.5–0.6 MBq/m^2, and for Pu was up to 27 kBq/m^2 The gamma background level on the surface of soil was as high as (126±29) μR/h, the β-flux density amounting to (819±268) β-particles/(min · cm^2).

The ^{90}Sr contamination density within the reference area chosen beyond the bounds of the EURT, amounted to 0.01–0.04 MBq/m^2, whereas for ^{137}Cs this parameter was at 4–5 kBq/m^2. The gamma background level on the surface of soil was equal to 7–11 μR/h, the β-flux density being 5–10 β-particles/(min · cm^2).

The areas are of similar geobotanical vegetation structure.

In order to measure morphometrical parameters as well as to determine the content of flavonoids and ^{90}Sr and ^{137}Cs radionuclides in plants, an average sampling was made for each area from 50 individuals in the fruit bearing stage (September, 2006).

Morphological parameters were determined using a method of computer image analysis. In order to measure metric parameters of leaves we carried out photographing in a "macro" mode with the use of a digital camera. The subsequent processing of pictures and the interpretation of results were carried out with the help of geoinformation technologies and spreadsheets using MapInfo and Excel 7.0 software packages. First of all the initial image was transformed into the Cartesian coordinate system. A vectoring of raster images was then performed with the subsequent calculation of morphometric parameters of a lamina such as the values of lengths, width, areas, perimeter [22].

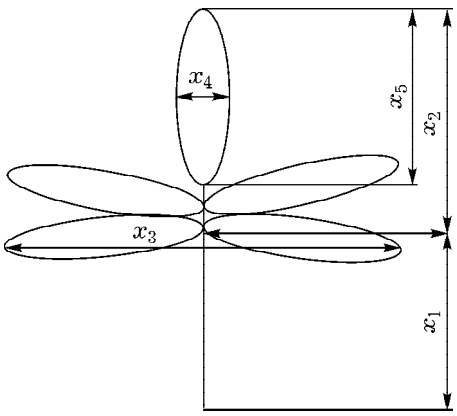

Fig. 1. Metric characteristics of *Pentaphylloides fruticosa* leaves (x_1– leafstalk length; x_2 – lamina length; x_3 – lamina width; x_4 – end lacinia width; x_5 – end lacinia length.

Figure 1 demonstrates an order in determining the metric characteristics of laminas.

We measured the length of each annual spear and counted the number of leaves on the latter.

The content of flavonoids (the total content, the content of flavonoid groups and separate components) in leaves of plants was determined using an HPLC method [23, 24]. A precisely weighed sample of as-harvested green plant material (0.5 g) was infused in 96 % ethanol during 20–30 days. Then it was exhaustively extracted with 70 and 96 % ethanol at T = 60–70 °C using a water bath [8]. The extraction efficiency was monitored with the help of a qualitative reaction toward flavonoids with 10 % NaOH solution. The extracts were joined together and the volume was then measured (usually it amounted to about 50–60 mL).

The extract (1 mL) was diluted with double distilled water up to the volume of 5 mL and passed then through a Diapak C16 concentrating cartridge (BioChemMac Co., Russia) in order to purify from impurities of hydrophylic nature. Flavonol glycosides were eluated from the cartridge using a small amount of 70 % ethanol, aglycons being eluated with 96 % ethanol. The eluates were joined together measuring the volume (usually it amounted to about 5–8 mL) and passing then the mixture through a membrane filter with pores of 0.45 μm in diameter.

The analysis was carried using an analytical HPLC system consisting of an Agilent 1100 liquid chromatograph with an UV spectrophotometric detector and a system for chromatographic data acquisition and processing (Germany). The separation was performed using a Hypersil ODS column 250 × 2.0 mm packed with octadecylsilica gel (C18), particle size being 5 μm in diameter. For chromatographing a gradient elution mode was used. As far as the mobile

phase is concerned, the content of methanol in the aqueous solution of orthophosphoric acid (0.1 %) was varied from 32 to 34 % during 25 min and from 34 to 55 % during the following 25 min. The eluent flow rate amounted to 0.25 mL/min, the column temperature being at 35 °C, the sample volume injected was equal to 5 μL. Before using the mobile phase it was filtered through a membrane filter with pores of 0.45 μm in diameter. The detection was carried out at the wavelength $\lambda = 360$ nm.

For the preparation of mobile phases we used extra-purity grade methyl alcohol and orthophosphoric acid, as well as double-distilled deionised water. For the preparation of reference samples we took the samples of quercetin, kaempferol, hyperoside and quercitrin (Fluka, Germany). Standard solutions were prepared with the concentration of 10 μg/mL in methyl alcohol. The injected sample volume amounted to 5 μL.

The quantitative determination of individual components in *P. fruticosa* samples was carried out according to the external standard technique as an optimal one for the chromatography analysis of multicomponent mixtures [23].

The content of individual components (C_x) with respect to bone-dry raw material was calculated according to the formula

$$C_x = 100C_{st}\, S_1V_1V_2/S_2M(100 - H)$$

Here C_{st} is the concentration of corresponding standard flavonol solution, μg/mL; S_1 is the peak area for flavonol in the sample under analysis, r.a.u.; S_2 is the peak area for a standard flavonol solution, r.a.u.; V_1 is the volume of eluate after washing flavonols out of the concentrating cartridge, mL; V_2 is the total extract volume, mL; M is the mass of the sample, mg; H is raw material humidity, %.

The content of flavonols was determined as the sum of quercetin glycosides, kaempferol glycosides and their free aglycons.

In order to determine the content of flavonol glycosides (quercetin glycoside and kaempferol glycoside separately) we carried out the analysis for aglycons such as quercetin and kaempferol formed after acid hydrolysis of corresponding glycosides. For performing the reaction of acid hydrolysis, to 0.5 mL of an aqueous ethanol extract were added 0.5 mL of a 2 M HCl solution and the mixture was then heated with a boiling water bath during 2 h. After cooling the diluted extract was passed through a concentrating cartridge, aglycons were washed off with 96 % ethanol and chromatographed using a gradient elution mode. In the mobile phase, the content of methanol in the aqueous solution of orthophoshoric acid (0.1 %) was varied from 45 to 48 % during 18 min.

The content of flavonol glycosides (quercetin and kaempferol glycosides separately) in *Pentaphylloides fruticosa* samples were calculated according to the content of free aglycons formed after acid hydrolysis. For the recalculation of aglycon concentration to obtain the concentration of corresponding glycoside we used conversion factors available from the literature; they are 2.504 for quercetin and 2.588 for kaempferol [23, 24].

The overall content of flavonoid compounds was estimated according to the sum of chromatographic peak areas registered at the wavelength $\lambda = 360$ nm, since for many flavonoids the absorption maxima are observed within the long-wave range of (362±14) nm which allows one to distinguish them easily from other classes of substances.

The determination of ^{90}Sr and ^{137}Cs radionuclide content was carried out using standard methods of β- and γ-spectrometry [25, 26].

All the biometric data were processed using the methods of variation statistics with the help of Excel 7 and Statistica 6 statistical software packages.

RESULTS AND DISCUSSION

The data obtained indicate that the maximum content of ^{90}Sr and ^{137}Cs in the aerial part of *Pentaphylloides fruticosa* is inherent in the plants growing over the area No. 1. It has been revealed that the accumulation of ^{90}Sr in leaves is more considerable as compared with that in stems, irrespective of the radionuclide contamination level in the areas. As far as ^{137}Cs is concerned, similar dependence is traced for the plants from the area No. 1. For the plants from the area No. 2 the specific ^{137}Cs activity in stems is somewhat higher as compared to that in leaves (Table 1).

An important parameter of the radiation contamination of plants is represented by ra-

TABLE 1

Radionuclide accumulation by *Pentaphylloides fruticosa* plants in various areas of EURT zone

Area number	Plant organ	Specific activity, kBq/kg		Accumulation coefficient	
		^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs
1	Leaves	355	1.0	0.9	0.1
	Stems	189	0.5	0.5	0.03
2	Leaves	23.1	0.3	0.2	0.3
	Stems	13.9	0.4	0.1	0.3

dionuclide withdrawal out of soil. The radiation contamination is estimated according to the accumulation coefficient (AC) calculated as the ratio of the specific radionuclide activity in dry matter of plants (expressed in Bq/kg) to the content of this radionuclide in the 20 cm thick layer of air-dry soil (in Bq/kg) [5]. The results obtained indicate that in leaves of plants harvested from the area No. 1 for ^{90}Sr AC ~ 1, whereas in stems AC = 0.5. For the plants from the area No. 2 this parameter is five-fold lower, which indicates a lower withdrawal of this radionuclide out of soil. Similar calculations for ^{137}Cs have demonstrated that for the plants growing within both areas AC < 1, which indicates a low withdrawal of this radionuclide out of soil of these areas, too.

The analysis of morphological characters of *Pentaphylloides fruticosa* cultivated under the conditions of different radionuclide contamination and under the reference conditions has shown that the radiation influence has resulted in a decrease in the photosynthesizing surface and a lengthwise decrease in annual spear and leafstalk gain; these parameters being reduced with the increase in irradiation (Fig. 2, Table 2). Most likely, this fact could be connected with the inhibition of growth processes and apical domination in spears, which is in a good agreement with the data from [5, 27, 28].

At the same time it is established that the number of leaves located on an annual spear for the plants growing within contaminated areas is higher as compared to that for the plants growing within the reference area. The maximum number of leaves is registered for the plants growing in the area No. 1. To all appearance, these plants exhibited the compensation for growth at the expense of the increase in number of leaves on an annual spear.

The comparative analysis of leave shape for *Pentaphylloides fruticosa* plants growing within the areas of the EURT zone with a various level of contamination has revealed no considerable differences (see Fig. 2). So, the value of leaf length-to-width ratio and the value of end lacinia length-to-width ratio are constant, they do not depend on the level of radionuclide contamination amounting to 0.7 and 3, respectively.

The following stage of the present work consisted in the studies on biochemical parameters of *Pentaphylloides fruticosa*.

As biochemical parameters under study we have chosen the total content of flavonoids, the sum of flavonols, the sum of glycosides, the sum of aglycons, quercetin glycosides, kaempferol glycosides and individual components.

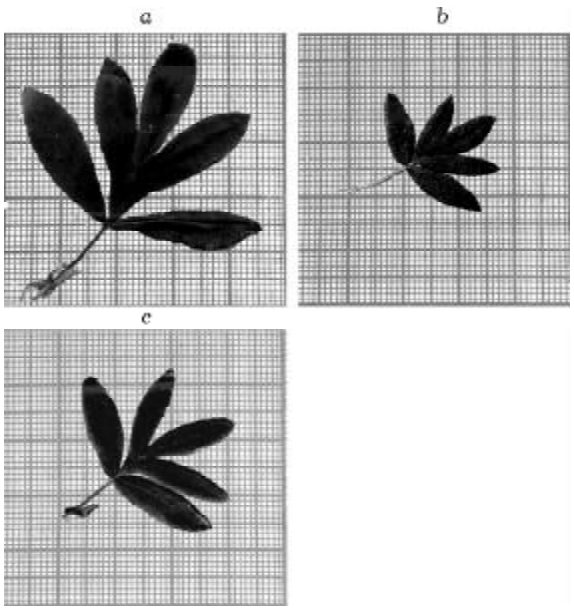

Fig. 2. Photographs of *Pentaphylloides fruticosa* plant leaves growing within the reference area (*a*) and within EURT areas No. 1 (*b*) and No. 2 (*c*).

TABLE 2

Morphometric parameters of *Pentaphylloides fruticosa* leaves harvested from the areas with different levels of contamination

Morphometric parameters	Reference area	Areas of EURT zone	
		No. 1	No. 2
Leaf area, mm^2	630±204	260±130	314±151
Leaf perimeter, mm	282±57	155±43	172±49
Leaf length (x_2), mm	30±6	19±4	21±5
Leaf width (x_3), mm	40±6	25±6	29±7
End lacinia area, mm^2	97±46	47±25	62±29
End lacinia perimeter, mm	47±11	32±8	36±8
End lacinia length (x_4), mm	22±5	15±4	16±3
End lacinia width (x_5), mm	6.6±1.7	4.7±1.3	5.7±1.7
Leafstalk length (x_1), mm	12±3	8±3	10±4
Spear length, mm	164±51	142±37	136±43
Number of leaves	10.6±2.9	11.7±2.8	11.1±3.8
Leaf length/Leaf width	0.7	0.7	0.7
End lacinia length/End lacinia width	3	3	3

Note. The data presented are corresponding to average value ± standard deviation.

The investigation of flavonoid composition using the HPLC technique has demonstrated that there are more than 13 compounds of flavonoid nature contained in the extracts of leaves of *Pentaphylloides fruticosa* cultivated under the conditions of different radionuclide contamination and under reference conditions (Fig. 3).

The comparative analysis of chromatographic prophiles for the extracts of samples under investigation has demonstrated that they exhibit similar polyphenolic composition. This fact indicates that the qualitative composition of the flavonoid complex of *Pentaphylloides fruticosa* leaves harvested from different EURT areas from the reference area does not change.

Basing on the results of the comparative analysis of retention time values for peaks of substances in the chromatographic profiles of reference samples and the samples under investigation, as well as on the UV spectral data the following flavonol glycosides have been identified: hyperoside, isoquercitrin, quercitrin and astragalin, and aglycons such as quercetin and kaempferol. Isoquercitrin and astragalin were

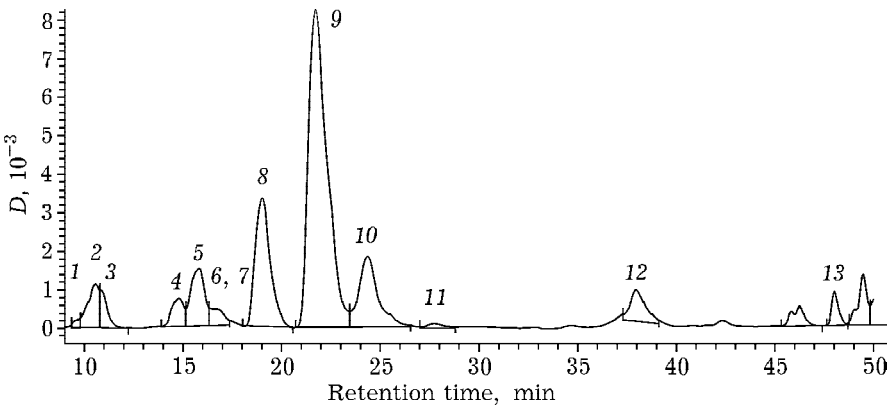

Fig. 3. Chromatographic profile of the extract of *Pentaphylloides fruticosa* leaves from the area No. 2 of the EURT zone: *1–3*, *6–9* – non-identified components, *4* – hyperoside (t_R = 14.78 min), *5* – isoquercitrin (t_R = 15.80 min), *10* – quercitrin (t_R = 24.35 mines), *11* – astragalin (t_R = 27.67 min), *12* – quercetin (t_R = 37.95 min), *13* – kaempferol (t_R = 48.00 min).

isolated in our earlier experiments from the plant under investigation, identified according to the results of chromatography analysis, UV absorption spectroscopy as well as ^{1}H and ^{13}C NMR spectroscopy [21]; they were used in the present work as standard samples.

The other components (see Fig. 3, *1–3*, *6–9*) are not identified up till now, but UV absorption spectral maxima for some of them have been registered during the chromatographing process in the online mode. For component *1* λ_{max} = 265, 357 nm, for component *2* λ_{max} = 278, 358 nm, for component *3* λ_{max} = 284, 354 nm, for component *6* λ_{max} = 257, 353 nm, for component *8* λ_{max}= 252, 367 nm, for component *9* λ_{max} = 255, 353 nm. Basis of these data these components have been considered to belong to flavonoid structures.

The results of flavonoid content determination (in total, in groups and as separate components) in leaves of *P. fruticosa* plants growing within various areas of the EURT zone as well as within the reference area have demonstrated that there are essential differences in the content of flavonols irrespective of similar qualitative flavonol composition.

TABLE 3

Content of flavonoids in *Pentaphylloides fruticosa* leaves (expressed in percentage with respect to bone-dry matter)

Component	Reference area	Area of EURT zone	
		No. 1	No. 2
1	0.02	0.02	0.02
2	Trace*	0.03	0.04
3	0.07	0.13	0.17
4 (hyperozide)	0.04	0.01	0.02
5 (isoquercitrin)	0.04	0.06	0.03
Sum of 6 + 7	0.16	0.14	0.18
8	0.01	0.52	0.17
9	0.66	0.91	0.92
10 (quercitrin)	0.30	0.07	0.16
11 (astragalin)	Trace*	0. 02	0.01
12 (quercetin)	0.03	0.08	0.05
13 (kaempferol)	0.04	0.01	0.03
Total flavonoid content	1.37	2.00	1.80
including:			
quercetin glycosides	0.77	1.74	1.27
kaempferol glycosides	0.01	0.05	0.04
Sum of flavonol glycosides	0.78	1.79	1.31
Sum of aglycons	0.08	0.09	0.08
Sum of flavonols	0.84	1.88	1.39

*Content less than 0.001 %.

The total flavonoid content, the sum of flavonols, the sum of flavonol glycosides and aglycons in leaves of irradiated plants has been revealed to be higher than those for the reference samples, and at the same time the difference increases with the increase in the contamination level of the areas (Table 3).

The analysis of the content of flavonol glycosides (quercetin glycosides and kaempferol glycosides separately) in leaves has demonstrated the content of quercetin glycosides for both areas as well as for the background to be higher as compared to the content of kaempferol glycosides. Moreover, it is established that with the increase the level of contamination the difference with respect to the reference is exhibited for quercetin glycosides to a greater extent than for kaempferol glycosides. To all appearance, it could be connected with the fact that the increase in the radiation level exerts a greater effect on quercetin glycosides as compared to kaempferol glycosides.

As a whole, the accumulation of quercetin glycosides and kaempferol glycosides exhibit the same dependence on the contamination level of the areas, as the total content of flavonols does: the maximum of these values is observed in leaves of the plants harvested from the most contaminated area No. 1.

The comparative analysis of the content of individual components in leaves of *Pentaphylloides fruticosa* growing within different EURT areas and within the background area has revealed three opposite dependences of the individual components content on the soil radionuclide contamination level. So, the concentrations of components *3*, *8*, *9*, isoquercitrin, astragalin and quercetin in leaves of plants growing within EURT areas is higher as compared to those for the plants from the reference area, this difference increasing with the increase in the radiation level.

For hyperoside, quercitrin and kaempferol an inverse relationship is observed: the content of these substances in plant leaves from contaminated areas of the EURT decreases as compared to that for the reference area, reaching a minimum in the plants harvested from the

most contaminated area No. 1. It was not possible to achieve a distinct separation of components *6* and *7* during the process of chromatographing; therefore their total content has been calculated. In a similar manner as for the component *2*, the content of the aforementioned components in plant leaves from impacted areas gradually raised as compared to that for the reference area, further a drop was observed for leaves of plants growing within the most contaminated area No. 1. The concentration of component *1* remained constant irrespective of the place of plant growing.

It should be noted that the role of separate components in the realization of the adaptive functions of flavonoids is unequal. The fact that for different plant species under man-caused and natural impact the content of either flavonoid structures (such as quercetin, kaempferol, myricetin and their derivatives) increases, is rather often mentioned in the literature [8, 29, 30]. From the results we obtained it follows that individual flavonoid components can form different types of the response of an organism to the radiation influence such as synergism, antagonism or indifference with respect to radiation. This fact is confirmed by data available in the literature [4]. Thus, to predict a resulting response to the influence of either factor is to a considerable extent problematic.

As it follows from our data, for *P. fruticosa* the resulting response to the influence of radiation is expressed by the increase in the content of flavonoids (for both total and group content). Quercetin, its glycosides (hyperoside, isoquercitrin, quercitrin) and non-identified as yet components such as *3*, *9* and *10* are the most susceptible components with respect to the increase in radioactivity.

In the course evolutionary development organisms are adapting to the action of either natural or man-caused factors developing the adaptation mechanisms. We have experimentally demonstrated that under radiation impact on plants *Pentaphylloides fruticosa* the intensity of metabolic processes increases and one can observe the changes in morphological parameters those consist in an increase in flavonoid biosynthesis as well as reduction of photosynthesizing surface, leafstalk and annual spear length are observed.

CONCLUSIONS

As the result of the studies carried out it has been shown by the example of *Pentaphylloides fruticosa* (L.) O. Schwarz that the radiation factor initiates adaptation processes affecting the biochemical reorganization of metabolism and morphological structure of plants.

In response to the radiation impact an increase in the biosynthesis of flavonoids is observed. A 2.3-fold increase in the content of flavonols is revealed (for both total and group content) in leaves of *P. fruticosa*, and as the contamination level grows the differences with respect to reference parameters increase. Quercetin glycosides are prevailing among flavonoids, their fraction in the total flavonoid content is as high as 87 %. Individual flavonoid components take part in the formation of different response types in an organism to radiation influence. There are quercetin, its glycosides (hyperoside, isoquercitrin, quercitrin) and non-identified components such as *3*, *9* and *10* considered among the most susceptible components with respect to the increase in radiation level. With the increase in radiation contamination the content of hyperoside, quercitrin and kaempferol is reduced, whereas the other flavonoid components, on the contrary, demonstrate an increase. The qualitative flavonoid content in leaves remains constant for both irradiated and reference plants.

Changes in morphological structures are demonstrated. A decrease in the surface of a leaf, a lengthwise reduction of annual spear and leafstalk gain, an increase the number of leaves at a spear are revealed, the majority of parameters exhibiting an increase in distinction with reference values as irradiation increased.

Different organs of *Pentaphylloides fruticosa* exhibit different accumulative ability with respect to radionuclides: the content of ^{90}Sr in leaves is higher as compared to stems irrespective of the contamination level, whereas for ^{137}Cs similar connection is not observed.

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