УДК 577.4:581.5:504.064:539.16

ADAPTATION PROCESSES IN BIOCOENOSES OF CONTAMINATED PLOTS OF THE SEMIPALATINSK TEST SITE

R.P. Plisak, S.V. Plisak

RGO Institute of Botany and Phytointroduction KN MES RK, Almaty, Kazakhstan

The article presents results of adaptation processes of main types of ecosystems (steppe, meadow, halophytic) and various types of disturbed ecosystems territories of the Semipalatinsk test site (STS). It was found that radiation pollution provokes change of morphological and anatomical structure of plants and leads to formation of some adaptation signs. Formation of adaptation signs of perennials and shrubs is expressed more clearly. Change of morphological and anatomical structure of plants happens more often in meadow (mesophyte) communities and at disturbed areas.

Radiation, as an environmental factor, causes in plants the formation of adaptive signs: changes in growth, development and reproductive function. A plant, like any biological system, adapts to a changing habitat by acquiring adaptive characteristics.

Radiosensitivity of plants depends on their cytological, biological and genetic characteristics, chemical composition and peculiarities of physiological processes. Ionizing training provokes growth retardation, loss of reproductive functions, and sterilization of pollen. Radionuclides, in combination with other ecological factors, cause significant changes in the vegetation cover. There comes a change in the species composition of communities, a change in their structure and biomass, coverage, stratum, direction and speed of successions.

The objects of research are the three main types of ecosystems (steppe, meadow, halophytic) territories of the Semipalatinsk Test Site (STS), formed at the power exposure dose (PED) 10–20 μR/h and 30–170 (200) μR/h, as well as various types of disturbed ecosystems PED (10–20 μR/h) and 120–1 600 μR/h.

Investigations of widespread zonal (steppe) ecosystems were conducted at the test site “Experimental field”. The territory of the test site is the most polluted area at STS. Main polluters of the territory are longliving radionuclides Cs^{137}, Sr^{90}, $Pu^{239,240}$. Content of Cs^{137} is 819 Bq/kg and Am^{241} – 12 386 Bq/kg in surface soil layer.

Investigated ecosystems occupy even gently sloped or flat plains between hills. Soil forming rocks are deluvial-proluvial sandy-skeleton sediments. Soils are light chestnut loamy or light loamy and rare – loamy sandy. They are characterised by not great depth of humus layer (till 30 cm), not great content of humus (till 3.0 %) and sufficient content of potassium and calcium. Soils develop in unfavourable hydrothermal conditions. Type of water regime is leaching. Supply of organic matters is insignificant. Moistening of zonal soils does not exceed 250–300 mm per year in conditions of decertified steppes. Shortage of moistening does not promote significant moving of hot particles or water-soluble ions of radioactive elements.

The main technogenic polluters of the investigated soils are Am^{241} – till 12 386 Bq/kg at the polluted plot and 13 Bq/kg at the control plot, $Eu^{152,154}$ – 3 Bq/kg at the polluted plot and <1.4 Bq/kg at the control plot, Cs^{137} – 53 Bq/kg at the polluted plot and 29 Bq/kg at the control plot. High concentration of Am^{241} is evidence of soil pollution by α-irradiators. Their content exceeds all permissible limits. Among β-irradiators (Sr^{90}, Cs^{137}, Co^{60}, $Eu^{152,154}$) high concentration of $Eu^{152,154}$ – 1 957 Bq/kg was revealed. The highest content of radionuclides is marked in surface soil layer (0–2 cm, 0–3 cm). It sharply decreases in lower soil horizons.

Radiation pollution did not affect physical and chemical properties of soils. Part of surface soil layer was removed under decontamination of the territory of test site “Experimental field”. It led to reduce of humus layer depth.

At present radioecological conditions following peculiarities of development of investigated xerophyte communities of *Stipa sareptana* + *Artemisia marschalliana* + *A. sublessingiana* + *Festuca valesiaca* (PED 150–170 μR/H) and of *Stipa sareptana* + *Artemisia sublessingiana* + *A. marschalliana* + *Festuca valesiaca* (PED 10 μR/H) were revealed:

1. No significant difference in species and ecobiomorphological composition at the polluted and control plots was revealed. Presence of *Ceratocarpus arenarius* at the polluted plot is evidence of strong anthropogenic influence on the territory.

2. Horizontal structure of the investigated community at the polluted plot is more heterogeneous than at the control plot. It is conditioned by continuation of the process of vegetation restoration after destruction by nuclear explosions and taking away of surface soil layer (decontamination of the territory) at the polluted plot. Because of the same reasons degree of total coverage and quantity of species in the community is lower at the polluted plot. Radiation pollution impact on vertical structure of the communities was not revealed.

3. Stimulation of growth of *Stipa sareptana*, increase of average weight of the plant and monocotyledonous plants were revealed at the polluted plot. Overground biomass is correspondingly higher due to the weight of monocotyledonous plants. It is 74.4 % of overground biomass.

4. Radioactive contamination provoked phenologycal displacement of some plants in the investigated community. Reproductive phase of *Artemisia marschalliana* and *A. sublessingiana* started earlier at the polluted plot.

5. Radioactive contamination provoked teratological transformations of *Spiraea hypericifolia, Artemisia marschalliana* and *Phlomis tuberosa.*

6. Decrease of rate of decomposition of organic matter in the investigated community was revealed at the polluted plot.

Investigations of meadow ecosystems were conducted in valleys of small rivers of low mountain massif Degelen. The main polluters of the territory are Cs^{137}, Sr^{90} and to the smaller extent Am^{241}, Co^{60}, $Eu^{152,154}$.

Investigated ecosystems (mesophyte communities developing on meadow soils) develop in low flood-lands and depressions of valley of small river and springs. According to moistening regime meadow soils are in conditions of sufficient or surplus moistening (ground supply and surface moistening). According to soil texture medium loamy and heavy loamy modifications of soil prevail. The heavier soil texture and even distribution of granulemetric elements by vertical profile are typical for soils of polluted plots. It conditions high capacity of cation exchange in soil layer of 0–50 cm. High content of humus (up to 19 %) and significant depth of humus horizon (up to 65 cm) are typical for meadow soils. The main polluters of considered meadow soils are Cs^{137} – till 3 166 Bq/kg at the polluted plot (till 111 Bq/kg at the control plot). Mainly surface soil layer (0–10 cm) of meadow soil is polluted by radionuclides. Pollution of technogenic radionuclides reaches background values at a depth of 30–50 cm. Surplus moistening of considered meadow soils promotes increase of humus content and dilution of concentration of technogenic radionuclides. It occurs at the expense of their additional dissolution under acidulation of soil solution by organic acids. Factors mentioned above promote radionuclide (Cs^{137}, Sr^{90}, Co^{60}, $Pu^{239,240}$) absorption by soil. They intensify mobility of radionuclides in system of soil—soil solution.

Following peculiarities of development of the investigated communities of *Calamagrostis epigeios* + *Galatella biflora* + *Sanguisorba officinalis* (PED 150 μR/H and 10 μR/H) in present radioecological conditions were revealed:

1. Significant differences in ecobiomorphological composition of plants constituting investigated communities at the polluted and control plots were not revealed.

2. Species diversity is significantly greater at the polluted plot. But it is not possible to separate impact of radiation pollution from impact of other anthropogenic factors in hydromorphous ecosystems. In this case they are: 1) surplus moistening; 2) influence of annual burning out of herbage; 3) demilitarisation of adits conditioned decrease (or decease) of water outflow from the adits. These reasons provoked significant difference in composition of accompanying species in the communities at the polluted and control plots.

3. Horizontal structure of the investigated community is heterogeneous at the polluted plot. But at the polluted plot heterogeneity of the structure is intensified by influence of above mentioned factors. Besides that, soil surface layer is disturbed in the investigated community on numerous areas. Radiation pollution impact on vertical structure of the communities was not revealed.

4. Growth stimulation of *Calamagrostis epigeios, Galatella biflora, Sanguisorba officinalis* is revealed at the polluted plot. Weight of one individual of the plants is increased. Weight of monocotyledonous and dicotyledonous plants and correspondingly weight of overground biomass is higher at the polluted plot. At the case range of factors (soil texture, salinization of surface soil layer, presence of carbonates and so on) affects development of overground biomass. But the most important factor is conditions of moistening. They were more favourable at the polluted plot.

5. Radioactive pollution provoked phenological displacement of some plants in the investigated community. Fruiting phase of *Sanguisorba officinalis* started earlier at the polluted plot. Blooming phase of *Galatella biflora* started later at the polluted plot.

6. Radioactive pollution provoked teratological transformations of *Melilotus albus, Potentilla virgata, Odontites serotina, Lepidium latifolium, Berteroa incana.*

Community of *Elytrigia repens* + *Inula britannica* (PED 100–120 μR/H) and com. of *Inula britannica* + *Elytrigia repens* (10–12 μR/H) were investigated on meadow drying soils. The communities develop on heightened areas of flood-lands of small rivers and springs in conditions of irregular surface flooding and low ground moistening. Texture of the soils is light loamy or sandy loamy. High content of humus is typical for the soils. Depth of humus horizon fluctuates from 34 up to 58 cm.

The main polluters of meadow drying soils are Cs^{137} with 4 130–8 504 Bq/kg at the polluted plot and 45–69 Bq/kg at the control plot. Soils are polluted by radionuclides in surface soil layer (0–10 cm). Content of Cs^{137} decreases till 4 Bq/kg at a depth of 25–35 cm.

Following peculiarities of development of the investigated communities in present radioecological conditions were revealed:

1. No significant difference was revealed in ecobiomorphological composition of plants constituting the communities at the polluted and control plots.

2. Species diversity at the polluted plot is significantly higher than at the control plot. Besides radiation pollution, other factors affect the community. They are appearance of radioactive springs after underground nuclear explosions and cease of water outflow after demilitarisation of adits, burning out of vegetation in valleys of small rivers and radioactive springs, intensive influence on soil surface (road construction, cluttering up

by debris and so on). Combined impact of these factors conditioned appearance numerous species (weed annuals and perennials, xerophyte dwarf semishrubs) which are not found at the control plot.

3. Horizontal structure of the investigated communities is heterogeneous at the polluted and control plots. It is more heterogeneous at the polluted plot because of influence of anthropogenic factors mentioned above. Influence of radiation pollution on vertical structure of communities was not revealed.

4. In present radioecological conditions plant coverage was lower at the polluted plot. Quantity of individuals of *Elytrigia repens* and *Inula britannica* per one square meter was lesser at the polluted plot. Weight of monocotyledonous and dicotyledonous plants and the whole overground biomass was lower at the polluted plot.

5. Radioactive pollution provoked phenological displacement of some plants in the investigated communities. Fruiting phase of *Potentilla virgata* started earlier at the polluted plot. Blooming phase of *Achillea asiatica* started later at the polluted plot.

6. Radioactive pollution provoked teratological transformations of *Melilotus albus, Potentilla virgata, Odontites serotina, Lepidium latifolium, Berteroa incana.*

Communities with dominance of *Achnatherum spleendens, Glycyrrhiza uralensis, Leymus angustus* (PED 130–140 μR/H and at the control 10–12 μR/H) were investigated on meadow stepping soils. The communities develop on heightened areas of valleys of small rivers in conditions of surface moistening and on depressions between hills under additional moistening and insignificant ground water supplying. Texture of meadow stepping soils is loamy or light loamy. High content of humus is typical for the soils. Depth of humus horizon is significant.

The main polluters of meadow stepping soils are Cs^{137} with 1 053–1 394 Bq/kg at the polluted plot and 25.6–55 Bq/kg at the control plot.

Following peculiarities of development of communities of *Glycyrrhiza uralensis + Leymus angustus + Achnatherum splendens* at the polluted plot and communities of *Achnatherum splendens + Glycyrrhiza uralensis + Leymus angustus* at the control plot in present radioecological conditions were revealed:

1. No difference was revealed in ecobiomorphological composition of plants constituting the investigated communities at the polluted and control plots.

2. Species diversity at the polluted plot is signifycantly greater than at the control plot. But years of investigations revealed that burning out of herbage (appeared numerous weed species) and disturbance of soil surface (road construction, cluttering up by debris, digging holes and so on) also promoted species diversity increase.

3. Horizontal structure of the investigated communities is heterogeneous at the polluted and control plots. Heterogeneity of horizontal structure at the polluted plot was strengthened by influence of the factors mentioned above. Impact of radiation pollution on vertical structure of the communities was not revealed.

4. In present radioecological conditions coverage in the investigated communities was lesser at the polluted plot. Quantity and height of individuals of *Achnatherum splendens* per one square meter were greater at the control plot. The greater quantity of individuals and the greater height of *Glycyrrhiza uralensis* were at the polluted plot. Weight of one individual of *Achnatherum splendens* was higher at the control plot and of *Glycyrrhiza uralensis* at the polluted plot. Weight of monocotyledonous plants was higher at the control plot. Weight of overground biomass was greater at the polluted plot. Blooming phase of *Galatella biflora* started later at the polluted plot.

5. Teratological transformations of plants in the investigated communities were not revealed.

Communities of *Leymus angustus* (PED 160 μR/H and at the control 10–12 μR/H) were investigated on meadow stepped soils. They develop at over-flood plain terraces of small rivers and valleys between hills in conditions of surface moistening. Ground water supply does not play significant role. Texture of meadow stepped soils is loamy or light loamy. Humus content reaches 15 % and the depth of humus horizon is 32 cm.

The main polluters of the soils are Cs^{137} (612–896 Bq/kg at the polluted plot and 21.3–46 Bq/kg at the control). Soils are polluted by radionuclides in surface layer 0–10 cm.

Following peculiarities of development of com. of *Leymus angustus* in present radioecological conditions were revealed:

1. There is no significant difference in ecobiomorphological composition of the main species constituting the investigated communities at the polluted and control plots. Presence of shrub of *Spiraea hypericifolia* at the polluted plot is conditioned by close to soil surface bedding of dense bedrock.

2. Species diversity at the polluted plot is significantly greater than at the control plot. But in this case repeated burning out of herbage promoted increase of species diversity at the polluted plot. It promoted appearance of many species, especially weeds.

3. Horizontal structure of com. of *Leymus angustus* is heterogeneous at the polluted and control plots. At the polluted plot heterogeneity is strengthened by fires, mechanical disturbance of soil and so on. Impact of radiation pollution on vertical structure of the investigated community was not revealed.

4. Living soil cover in present radioecological conditions is almost the same at the polluted and control plots. Height and weight of one individual of *Leymus angustus* is higher at the polluted plot. Weight of monocotyledonous plants is higher at the polluted plot. Weight of dicotyledonous plants is also higher at the polluted plot. Weight of overground biomass is greater at the polluted plot. Additional moistening greater than at

the control plot together with radiation pollution played significant role in development of the greater height and weight of one individual of *Leymus angustus*, the greater weight of monocotyledonous and dicotyledonous plants and the whole overground biomass in the investigated community at the polluted plot. Significant supply of moisture was formed in soil in the first half of vegetation period because of melted and rain water. Radiation pollution provoked phenological displacement of some plants in the investigated community. Fruiting phase of *Leymus angustus* started earlier at the polluted plot. *Stipa capillata* and *Festuca valesiaca* did not develop reproductive organs.

5. Teratological transformations in communities of *Leymus angustus* at the polluted plot (PED 160 μR/H) were not revealed.

Halophyte ecosystems occupy saucer-shaped depressions of plains between hills and slopes of sor depressions. Soil forming rocks are deluvial-proluvial sediments. Soils are solonchaks ordinare. They develop in conditions of additional moistening by slope flowing of water from melted snow and mineralised underground waters. Texture of ordinare solonchaks is loamy and light loamy. Type of water regime is permacidous leaching and exhudational. Humus content is 2.0–2.4 %. Depth of humus horizon is 36–40 cm.

Distinctive property of ordinare solonchaks is insignificant content of easy soluble salts.

The main technogenic polluter of investigated soils is Cs^{137}. Its content is 2 256 Bq/kg at the polluted plot and 24.9 Bq/kg at the control plot. Content of other radionuclides reaches: $Eu^{152,154}$ – 91.1 Bq/kg at the polluted plot and 3.1 Bq/kg at the control plot, Am^{241} – 63 Bq/kg at the polluted plot and 62.1 Bq/kg at the control plot, Co^{60} – 59 Bq/kg at the polluted plot and <1.1 Bq/kg at the control plot. Signs of radionuclide impact on physical and chemical properties of soils were not revealed.

Following peculiarities of development of investigated communities of *Halimione verrucifera* + *Halocnemum strobilaceum* (PED – 40–50 and 10–12 μR/H at the control) in present radioecological conditions were revealed:

1. No difference between species and ecobiomorphological composition of the most of plants constituting investigated communities at the polluted and control plots was revealed. Species diversity is significantly higher at the polluted plot. But ecological conditions of the polluted plot are more dynamic: soils are formed under influence of capillary border of underground waters, underground water level decreases from Spring till Autumn and provokes changes in water and salt regime of soils. Plants with different rhythm of development, ecological type and life form develop in these conditions differently according to soil moisture. Therefore, species composition at the polluted plot is more various.

2. Horizontal structure of the investigated community is heterogeneous at the polluted and control plots. Influence of radiation pollution on vertical structure of the investigated community at the polluted and control plot was not revealed.

3. Satisfactory development of *Halocnemum strobelaceum* was marked at the polluted plot and good and excellent at the control plot. Average height, weight of one individual and average weight of root of one individual of *Halocnemum strobilaceum* is lower at the polluted plot. Weight of underground biomass and weight of dicotyledonous plants is lower at the polluted plot. But the influence of radiation pollution under its low level can't be separated from influence of other ecological factors. In the present case, obviously, the main of them is moisture degree.

4. Phenological displacement of dominating plants was revealed. Fruiting phase of *Halimione verrucifera* and *Halocnemum strobilaceum* started later at the polluted plot.

5. Plants with teratological transformations at the polluted plot (PED 30–45 μR/H) were not revealed.

Brief comparative analysis of morphological structure of 8 plants (annuals, biennials, perennials, dwarf semishrubs, shrubs) from the polluted and control plots revealed following changes:

1) inhibition of growth (*Berteroa incana*, *Melilotus albus*, *Kochia sieversiana*, *Rosa laxa*); 2) coiled stem (*Phlomis tuberosa*); 3) change of direction of stem growth (*Lepidium latifolium*, *Melilotus albus*, *Phlomis tuberosa*); 4) shortening of internodes (*Rosa laxa*); 5) change of type of branching of stem (*Rosa laxa*) and dichotomy of stem (*Lepidium latifolium*, *Calamagrostis epigeios*); 6) congestence of offshoots (*Rosa laxa*); 7) change of section of stem (*Melilotus albus*, *Phlomis tuberosa*); 8) change of shape of blade (*Lepidium latifolium*, *Kochia sieversiana*); 9) change of dimensions of blade (*Rosa laxa*, *Lepidium latifolium*, *Kochia sieversiana*); 10) chlorosis of leafs (*Rosa laxa*, *Lepidium latifolium*); 11) wrinkled leafs (*Lepidium latifolium*); 12) formation of galls precipitation (*Artemisia marschalliana*, *Rosa laxa*); 13) disturbance of phyllotaxis (*Lepidium latifolium*); 14) absence of anthers or stamens (*Melilotus albus*, *Phlomis tuberosa*); 15) change of shape of ovary (*Melilotus albus*).

Following changes of anatomical structure of organs of the investigated plants were revealed: 1) increase of dimensions of primary bark (*Berteroa incana*, *Melilotus albus*, *Phlomis tuberosa*, *Artemisia marschalliana*) or decrease of dimensions of primary bark (*Lepidium latifolium*); 2) decrease of volume of central cylinder (*Lepidium latifolium*, *Kochia sieversiana*); 3) decrease of dimensions of pithy parenchyma (*Lepidium latifolium*, *Kochia sieversiana*) or increase of dimensions of pithy parenchyma (*Berteroa incana*, *Rosa laxa*); 4) great development of phloem elements (*Melilotus albus*); 5) increase of square of conductive bunches (*Kochia sieversiana*) or decrease of square of conductive bunches

(*Lepidium latifolium*); 6) increase of dimensions of epidermis cells (*Lepidium latifolium*).

Thus, radiation pollution provokes change of morphological and anatomical structure of plants and leads to formation of following adaptation signs: appearance of coiled stem; change of growth direction and type of branching of stem; congestion of offshoots and shortening internodes; change of stem section, shape of blade and its dimensions; increase/decrease of dimensions of primary bark; increase of dimensions of pithy parenchyma and constituting cells; increase of square of conductive bunches; change of dimensions of epidermis cells. Formation of adaptation signs of perennials and shrubs is expressed more clearly. Change of morphological and anatomical structure of plants happens more often in meadow (mesophyte) communities and at disturbed areas.

СЕМЕЙ СЫНАҚ ПОЛИГОНЫНЫҢ ЛАСТАНҒАН ТЕЛІМДЕРІНДЕГІ БИОЦЕНОЗДАҒЫ БЕЙІМДЕЛУ ҮДЕРІСТЕРІ

Р.П. Плисак, С.В. Плисак

ҚР БҒМ ҒК Ботаника және фитоинтродукция институты РМК, Алматы, Қазақстан

Мақалада, түрлі типтердегі (далалық, жайылымдық, галофитті) экожүйенің, сонымен бірге Семей сынақ полигонының (ССП) аумағындағы бұзылған экожүйенің негізгі типтеріндегі бейімделу үдерістерін зерттеу нәтижелері келтірілген. Радиациялық ластанулар өсімдіктердің морфологиялық және анатомиялық құрылымының өзгеруіне әсер ететіні және бірқатар бейімделу нышандарының пайда болуына алып келетінін анықталды. Көпжылдық және бұта-шілікті өсімдіктердің белгісінің қалыптасуы айқын көрінеді. Өсімдіктердің морфологиялық және анатомиялық құрылымының өзгеруі жайылымдық (мезофитті) қауымдастықта және бұзылған телімдерде жиі орын алатыны белгілі болды.

АДАПТАЦИОННЫЕ ПРОЦЕССЫ В БИОЦЕНОЗАХ НА ЗАГРЯЗНЕННЫХ УЧАСТКАХ СЕМИПАЛАТИНСКОГО ИСПЫТАТЕЛЬНОГО ПОЛИГОНА

Плисак Р.П., Плисак С.В.

РГП Институт ботаники и фитоинтродукции КН МОН РК, Алматы, Казахстан

В статье приведены результаты исследования адаптационных процессов основных типов экосистем (степные, луговые, галофитные), а также различных типов нарушенных экосистем территории Семипалатинского испытательного полигона (СИП). Установлено, что радиационное загрязнение провоцирует изменение морфологического и анатомического строения растений и приводит к образованию ряда адаптационных признаков. Формирование признаков адаптации многолетних и кустарниковых растений выражено более отчетливо. Изменение морфологического и анатомического строения растений происходит чаще в луговых (мезофитных) сообществах и на нарушенных участках.