Selenium (Se) is an essential element in the human nutrition. The interest in Se grows due to its importance for health, its use as a preventive means against cancer and infringement of metabolism [1]. It has one of the narrowest ranges between nutrition insufficiency (40 μg Se /day) and toxicity (400 μg Se /day) [2]. The role of selenium in an organism is determined first of all by the fact that it forms a part of the most important antioxidative enzymes – the Se-dependent glutathione peroxidase – which protects cells from accumulation of peroxide oxidation products.

The importance of Se to higher plants is widely discussed and no common opinion is found. Probably, the narrow range of utility is characteristic of plants as well as animals. High concentrations of Se are harmful to plants whereas low concentrations can influence positively [3]. Search for the plants accumulating Se is being conducted [4].

The numerous researches point to the role of selenium as a component of the antioxidant protection of plants under the stress conditions. Selenium regulates the parameters of the plant water exchange in the conditions of soil drought and hypothermia [5, 6]. Functioning as an antioxidant, selenium provides plants with stability to external factors and hence with realization of potential efficiency of a species and a grade. However, possible effects of selenium on regulating a plant growth and development are not clear so far.

**The research purpose.** The purpose of our work was to study the influence of selenium on accumulation of biologically active substances and morphogenesis of the plants Lactuca sativa L. depending on the type of an ion applied.

**Methods.** The object of the research was the soil culture of the sheet salad of the “Gourmet” variety. The plants were cultivated in the greenhouses under the polyethylene film on sod-podzolic soil of the Tomsk region. The early-ripen variety contained anthocyanins, which improved its nutritious properties. The plants were cultivated from the seeds treated with selenite and sodium selenate (40 μg Se mL⁻¹). The control plants were cultivated from the seeds treated with water. The treatment with selenium provided the influence of this element on the stages of seed germination and the seedling growth.

Morphological (a dry biomass and the sizes of the structural elements of shoots) and biochemical (the contents of photosynthetic pigments, ascorbic acid, anthocyanins and flavonoids sum) parameters were specified.

The content of chloroplast pigments (chlorophylls a and b, carotenoids) was determined by a spectrophotometric method in 96 %-alcoholic extracts of a vegetative material. The extinction of the solutions was measured by the spectrophotometer “Shimadzu UV-1650” (Japan) at the wavelengths 664.2, 648.6 and 470 nm, for chlorophylls a and b, and carotenoids accordingly. The concentration of the pigments solutions was calculated using the formulae from [7].

The quantitative determination of the aggregate contents of flavonoids sum in the plants was made using the method of flavonoids complexation with aluminum chloride with the subsequent spectrophotometric determination of the solution extinction at 415 nm wavelength. Rutin served as a standard solution [8]. A quantitative determination of the ascorbic acid contents in the plants was made by the method from [9]. The spectrophotometric determination of the anthocyanins contents in the plants was performed by the method from [9].

The data are submitted in the figures as the arithmetic average morphological (n=50) and biochemical (n=5) parameters with the confidential intervals regarding Student’s criterion for 95 % level of significance [10]. Comparing the plant groups treated with different forms of selenium the authors revealed statistically the important differences in the investigated parameters from those of the control (p<0.05).

**Results and discussion.** The productivity process of plants is defined in many respects by their productivity of photosynthesis. It involves the organization of the photosynthetic apparatus and its activity and is characterized by the total area of the leaves surface, the contents of photosynthetic pigments and the accretion of a dry biomass.

During the experiment the identical stimulating influence of the preseeding treatment of seeds with sele-
nite and sodium selenate on stretching of a stalk and a leaves area was recorded (Fig. 1). The similar influence of sodium selenite was observed on wheat [11].

![Fig. 1. The stalk length and leaves area of 60-day-old plants Lactuca sativa L. depending on the form of selenium. * The distinctions are authentic as compared with the control at р<0.05](image1)

The elongation of a salad shoot was accompanied by various processes which were different in the intensity and controlled by selenite and selenate ions. The treatment with sodium selenate twice increased the leaves biomass, a stalk and a root of the plants under experiment as compared with the control (Fig. 2), while the treatment with sodium selenite has not changed accumulation of a dry mass by the experimental plants. It testifies to different speed of influx and assimilation of ions or their different activity in regulating the oxidation-reduction status of a plant, and, consequently, synthetic processes.

![Fig. 2. The content of a dry mass of 60-day-old plants Lactuca sativa L. cultivated with selenite and sodium selenate. * The distinctions are authentic as compared with the control at р<0.05](image2)

The analysis of the contents of the biologically active substances also showed its dependence on the nature of the selenium ions. Selenium changed the level of the photosynthetic pigments (Fig. 3).

The selenite ion increased the contents of carotenoids and chlorophyll $a$, whereas the selenate ion reduced the level of carotenoids and increased the level of chlorophyll $b$. The effect of sodium selenate created the conditions for active oxidation of the chlorophyll $a$. Decrease in the contents of the carotenoids which carry out a protective function from a photooxidation of chlorophyll $a$ could cause it [12].

![Fig. 3. The content of the photosynthetic pigments in the leaves of Lactuca sativa L. treated with selenite and sodium selenate: Chl $a$ – chlorophyll $a$, Chl $b$ – chlorophyll $b$, Car – carotenoids. * The distinctions are authentic as compared with the control at р<0.05](image3)

A similar change in the photosynthetic pigments level is likely to have been connected with different effects of the selenium ions on the oxidation-reduction status of leaves. An oxidative stress generates reactive oxygen species (ROS). The ascorbic acid is one of the important components regulating the oxidation-reduction status of a cell. It is an important antioxidant in the photosynthesizing and non-photosynthesizing tissues. The ascorbic acid protects plants from an oxidizing stress caused by the environmental factors preventing from the ROS accumulation [13]. Light adaptation of plants to their irradiation UV light is shown at the initial stage of the ontogenesis through synthesis and accumulation of ascorbic acid, change of dynamics of level of photosynthetic pigments [14].

In our experiment the sodium selenite increased the ascorbic acid content in the upper younger leaves as compared with the control whereas sodium selenate reduced its content (Fig. 4).

![Fig. 4. The ascorbic acid content (AA) in the plant Lactuca sativa L. treated with selenite and sodium selenate](image4)

In our earlier researches it was shown that sodium selenite raised the content of the biologically active substances (the carotenoids, coumarins and flavonoids) in the edaphic culture during a presowing treatment of seeds [15].
The flavonoids are the other group of the compounds participating in the oxidation-reduction processes like the ascorbic acid and selenium [16]. The action of different selenium ions similarly changed the contents of the flavonoids sum in the salad leaves identically (the data are not adduced).

The anthocyanins are one of the flavonoids groups [16, 17]. They are the pigments actively absorbing the UV-radiation [17]. The anthocyanins can protect chlorophylls from photooxidation. Compared with the other components they are the best indicators of an oxidative plant stress caused by the external factors. Having the antioxidative characteristics they protect plants from appearance of free radicals [18].

In our experiment the action of sodium selenite has increased the anthocyanins contents in the lower leaves as compared with the control whereas the sodium selenate reduced their contents (Fig. 5). The latter circumstance could also serve as the reason for increase in the chlorophyll $b$ level under the natural illumination which is rich in the UV-radiation.

Other authors showed the Se role in protecting plants against the UV-B negative radiation. Se considerably increased the level of antioxidants and reduced the membranous peroxide oxidation of lipids in the above-ground parts of wheat plants exposed to the increased UV-B radiation [19]. In addition, Yao and et al. (2010) have shown that the Se treatments have considerably reduced the ROS content accumulation in the roots of wheat seedlings grown up under the enlarged dose of UV-B radiation [19].

The distinctions of the salad morphological and biochemical parameters under the action of different forms of selenium could be also associated with the change in the hormonal status of plants. We showed the influence of sodium selenite on growth-stimulant activity of the brassinosteroids [20]. Joint action of active groups of gibberellins and brassinolide on growth and development of plants *Arabidopsis thaliana* has been studied [21].

**Conclusion**

The results of researches have shown that the presowing treatment of seeds with selenium ions (selenite and selenates ions) has a stimulating effect on the elongation of the structural elements of the plants shoots *Lactuca sativa* L. and the content of the chlorophylls sums.

The specificity of action of different selenium ions consists in regulating the synthesis of the biologically active substances.

The effect of the sodium selenite increased the accumulation of the carotenoids, ascorbic acid and anthocyanins in the *Lactuca sativa* L. leaves.

The most active accretion of a shoot dry biomass has taken place under the influence of sodium selenate. This fact can be explained by reducing the diversion of the photosynthesis products for the synthesis of the above-mentioned antioxidants.

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РОЛЬ РАЗНЫХ ФОРМ СЕЛЕНА В РЕГУЛЯЦИИ МОРФОГЕНЕЗА И СОДЕРЖАНИЯ БИОЛОГИЧЕСКИ АКТИВНЫХ ВЕЩЕСТВ РАСТЕНИЙ Lactuca sativa L.

Результаты исследований показали, что предпосевная обработка семян селенитом и селенатом натрия оказывает стимулирующий эффект на растяжение структурных элементов побега растений Lactuca sativa L. и содержание суммы хлорофиллов. Специфика действия разных ионов селена заключалась в регуляции синтеза биологически активных веществ и сухого вещества.

Ключевые слова: Lactuca sativa, селен, морфогенез, хлорофиллы, каротиноиды, аскорбиновая кислота, антоцианы.

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