The effects of the impact of tourists can also be seen in the area directly adjacent to the trail, at a distance of 0,7–1,0 m the soil density was 1,33 and exceeded this figure for undisturbed soil by 1,22 times, which is shown in (Fig. 2).

Conclusion

The study of the protected area “Rock Zerkalo” showed that the anthropogenic impact is most noticeable in the change in soil density on the network of trails and in the immediate vicinity of it. The process of soil compaction at this site is associated with the recreational load exceeding 6 times of the average norm.

Summing up, we note that the results and data obtained in the course of the study can be used in lectures and practical classes on ecology as a demonstration material.

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Toxic Effect of Nanoparticles on Plant Resistance (on the example: Radish (*Raphanus sativa* L.), Lettuce (*Lactuca sativa* L.), Peas (*Pisum sativa* L.) and Coriander (*Coriandrum sativum*))

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Abstract

The given article is devoted to the study of the choice of test-objects due to the biotesting method. Analysis of the responses of the same level types of biological organization and their habitat to the effect of nanoparticles is carried out. Most resistant organisms to toxic effects of nanoparticle solutions were identified.

Keywords: biotesting, test-object, plants, ecology, nanoparticles, seeds, test-organisms.

Аннотация

Данная статья посвящена изучению выбора тест-объектов для проведения исследований методами биотестирования. Был проведен анализ ответных реакций представителей одного уровня биологической организации и среды обитания на воздействие наночастиц. При подведении итогов выявлены организмы, наиболее устойчивые к токсическим воздействиям растворов наночастиц.

Ключевые слова: биотестирование, тест-объект, растения, экология, наночастицы, семена, тест-организмы.

Introduction

At present, the determination of the level of contamination and toxicity of environmental objects, as well as materials, products and various types of waste cannot be established only on the basis of chemical research methods [6]. Biotesting enables to quickly obtain an integral assessment of toxicity at a particular point of time.

The aim of this work was to experimentally identify under laboratory conditions the possibility of annual plants using as test objects to determine the resistance of different plant species to the toxic effects of nanoparticles.

The plants are a necessary and binding component of any ecosystem [2, p. 95]. They have the ability to efficiently concentrate and convert substances in the environment, which increases the sensitivity and informativeness of their use for environmental quality control.

Methods

Biotesting is an experimental method of determining the toxic effects of physical, chemical and biological disadvantages of the environment, potentially harmful to living organisms. The basis of biotesting is to compare the reactions of organisms to the effects of a set of factors contained in the analyzed sample compared to a control sample. Organisms used in biotesting are commonly referred to as test organisms or test objects. The effects chosen to evaluate the state of the test environments are called test reactions. [3; 5].

Biotesting of higher plants is called phytotesting [4]. In this study, we used the following species: radish (*Raphanus sativa* L.), lettuce (*Lactuca sativa* L.), pea (*Pisum sativa* L.), coriander (*Coriandrum sativum*).

The choice of these seeds is argued by the following qualities: a) preferable small seeds with a small supply of nutrients, b) simplicity of cultivation, c) nutrient assimilation.

The experiment was conducted according to the methodological recommendation (2.1.7.2297-07). All seeds were sprouted in Petri dishes. At the beginning of the study, all seeds were spread out on filter paper in an amount of 30 pieces. Five ml of the test solution was poured into the cup, and 5 ml of distilled water was added to the control variant. The level of liquid was below the surface of the seeds. The seeds were counted according to GOST 12038-66; parameters of root and shoot weights and root length were registered [1]. To determine the average value of the parameters, the experiment was conducted in three parallels.

According to the importance of sprouting energy as per GOST 12038-66, we measured the weight of seedlings and roots, as well as the length of the maximum developed root in control samples, and with the introduced solution of nanoparticles.

The statistics of growth indices in the studied samples, relative to the control sample, were calculated by the formula:

$$I = 100\% \times (\overline{X_K} - \overline{X_0}) / \overline{X_K},$$

- where X_K and X_0 are the average values of the studied indicators in the control and experiment, respectively.

Each series of experiments was carried out three times.

Analysis and research results

To determine the most sustainable test object in response to nanoparticle solutions of different concentrations, we studied the reactions of radish, lettuce, peas, and coriander in response to the toxic effects of nanoparticles. The average values of the parameters determining the sustainability of the test objects are shown in Table 1.

According to the data (Table 1), we concluded that peas and radish are the most resistant test objects to chemical effects.

Table 1

Results of parameter response calculations on the toxic effects of nanoparticles

Test object tupe	Relative parameters, %			
	Germination energy	Mass of shoots	Mass of roots	Root length
Radish	102,2	107,0	91,7	93,0
Lettuce	89,6	94,3	92,3	91,9
Peas	104,75	110,0	94,8	96,7
Coriander	84,5	84	89,25	88,5

Having studied the response of the relative parameters of the test objects to the nanoparticle solution, we can conclude that coriander turned out to be the most sensitive test sample.

This test-object gives a fast response to the toxic effects of nanoparticles in water by morphological signs: slow growth, underdeveloped roots and shoots, relatively normal plant growth.

Thus, the most sustainable test sample turned out to be peas. The relative parameters of the researched object in the nanoparticle solution turned out to be higher than those of the control sample.

The peas is an accumulator plant. It accumulates in its tissues the pollutant or harmful metabolic products produced by pollutants without visible changes. When exposure to pollutants is more prolonged and the maximum allowable concentration rises, different responses occur for a given species, expressed in depressing changes in relative parameters. Growth rate, productivity decreases, shoots have a painful view, and the duration of phenological phases is disrupted.

Analyzing the obtained data, which are presented above, the diagram is compiled showing the resistance of the test objects to nanoparticle solutions (Fig. 1).

When the concentration of nanoparticle solution is increased, the test objects react with a decrease in seed germination and morphometric parameters of lettuce and coriander seedlings, except for radish and peas.

Figure 1. Diagram of the relationship of test-object parameters to the chemical effects of nanoparticle solutions

All the objects reacted individually to the injected solution and the increase in its concentration. Depressing signs were observed on roots and shoots, relative to the control sample. Small concentrations of the solution had a positive effect on the increase of shoot weight and germination speed than in the sample with control water.

Conclusions

Having studied the selected test objects, we can conclude that small concentrations of nanoparticle solutions have a positive dynamics of seed growth and increase in shoot mass. With increasing concentration, a depressing effect was observed on all test samples. Peas turned out to be the most resistant of the seeds (*Pisum sativa* L.). This crop was shown to be feasible because it showed a good reproduction of results in the experiments, unlike such test samples as coriander and lettuce.

To sum up, we note that the results of the study can be used in lectures and practical classes on nanotechnology as a demonstration material.

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