The plant resistance to oil contamination in soil

K G Tutarashvili1, E E Nefed’eva1, A A Okolelova1,2, T N Dronova3 and V F Zheltobryukhov1

1 Volgograd State Technical University, Volgograd, 400005 Russia
2 Volgograd State Agricultural University, Volgograd, 400002 Russia
3 Federal State Budget Scientific Institution the All-Russian Research Institute of Irrigated Agriculture, Volgograd, 400002, Russia

E-mail: kseniatutarashvili1996@mail.ru

Abstract. Research in improvement of cleaning efficiency of environment from oil products is relevant. It has a great practical and economic significance. Special attention has been given to means and materials used in the reclamation of oil-contaminated soils. Phytoremediation, the promising direction, is especially distinguished. It is necessary to select plants are resistant to oil pollution in the soil.

1. Introduction

The deteriorating environmental situation is well known to be a result of human activity. The most common causes of environmental pollution, especially soil, in the central and southern parts of the country are oil and oil products. According to the latest report of the Ministry of Natural Resources and Environment of the Russian Federation for 2018, the negative impact of oil products on the state of the soil, atmosphere, water, plant and animal organisms is estimated at 5.1 billion rubles [1].

In the zones of technogenic impact, the bulk of the incoming pollution with oil and oil products, as a rule, is located in the «atmosphere-hydrosphere-lithosphere» system. As a result of pollution of ecosystem components by oil and oil products through the air, water and soil environment, pollutants enter biological cycles and individual living organisms, their further transformation, accumulation, redistribution and movement.

2. The influence of petroleum products in soil on plants

Oil products contained in the soil have a negative impact on all living organisms of flora and fauna, affect growth and development, and also cause changes in morphological parameters and a decrease in productivity. Vascular plants are especially susceptible to harmful effects due to their direct attachment to the soil. Plants are the basis of an ecosystem, and the state of the biogeocenosis can be monitored by the emerging deviations of morphological characteristics and physiological reactions of plants. In addition to the direct toxic effect of oil pollution in the soil, it can have a mutagenic effect on plants [2].

Previous studies have indicated not only a negative, but also a positive effect of oil pollution on plant productivity. The effect depends on a number of factors. For example, the concentration and type of oil products, the duration and conditions of exposure, the type of plants and soil climatic conditions. It was found that the low concentration of oil products in the soil does not have a significant effect on plants. Some studies even support a stimulatory effect on plant growth when the concentration of
petroleum products in the soil is low. However, with an increase in the content of oil in the soil, the inhibitory effect of oil products begins to appear [3].

3. Methods for combating soil pollution with oil products

The restoration of oil-contaminated soil is a complex and lengthy process. Knowledge of the general principles and methods of soil restoration and their application to specific natural conditions is an important task that is of great importance for the preservation of the biosphere. The development of methods for cleaning soil from oil pollution is one of the most important tasks in solving the problem of reducing anthropogenic impact on the environment.

For the successful restoration of contaminated soils, an integrated approach is required, including both the measures of the technical stage of reclamation and the biological stage, at the final stage of which the sowing of resistant plants of the local flora is carried out is phytoremediation.

At the first stage, engineering and technical and agrochemical measures are carried out, namely, the removal of oil, the subsequent loosening and moistening of the soil. The second biological stage includes the activation of the vital activity of the microbiota. The third stage is aimed at restoring the vegetation cover by sowing oil-resistant grasses. The criterion for the completion of remediation work is such a residual oil content at which the initial growth of plants is possible [3]. Compared to traditional methods of restoration of oil-contaminated soil, phytoremediation is universally recognized as safer and more economical [4].

Modern researchers identify many relevant methods with the use of phyto-meliorative treatment, which are becoming the most frequently used in the purification of soils contaminated with oil products. The methods include the stage-by-stage implementation of a cycle of restoration work with phytomeliorative treatment carried out with suspensions from micromycetes [5], oil-oxidizing bacteria [6], brewing waste – brewer's grains, sawing and planing waste [7]. However, the use of these methods is associated with a number of disadvantages, namely the high cost of the used suspensions and biological products, the need to create certain temperature conditions and preliminary complex preparation of drugs, the inaccessibility of materials and the problem of waste storage and storage. It was also found that the introduction of artificial biological products into the soil can pose a significant danger to the functioning of biocenoses [2].

In connection with the indicated disadvantages of methods for bioremediation of oil-contaminated soils, the most promising methods are based on sowing resistant plants, preferably local flora - phytoremediation. At the same time, the search for cultivated and wild-growing plants with high resistance to oil pollution of the soil is gaining popularity. The use of such plants makes it possible to simultaneously solve the problem of cleaning oil-contaminated soils, the problem of storing production and consumption waste, and the problem of the safety of using remediates.

4. Aim of the study

The experimental studies were aimed to analyze the effect of oil contamination in the soil on the ability to grow in some plants, as well as to determine the culture in order to use it for phytoremediation of oil contaminated soil. Barbarea vulgaris (Barbarea vulgaris L.) of Brassicaceae family, white mustard (Sinapis alba L.) of Brassicaceae family, trifoilium repens (Trifolium repens L.) of Fabaceae family and cress (Lepidium sativum L.) of Brassicaceae family were been chosen for the experimental studies [8].

5. Research methodology

For the research, the following concentrations of oil in the substrate were used: 0 ppm at control sample, 500 ppm, 1000 ppm, 2000 ppm, and 3000 ppm. To exclude the influence of soil microflora and soil sorption properties, we used pure river sand moistened with Gelrigel solution. Each Petri dish was filled with 50 g of sand, 15 ml of a Gelrigel solution, oil and 15 seeds of the test plant. The studies were carried out in 2-3 fold repetitions. The influence of oil was assessed by the germination of seeds, as well as by the morphological parameters of plants.
And also to study the possibility of using cress (Lepidium sativum L.) and trifolium repens (Trifolium repens L.) for phytoremediation of oil-contaminated soil, an analysis of changes in the dry weight of seedlings was carried out depending on the concentration of oil pollution in the substrate (tables 3-4).

6. The research on the seeds of Barbarea vulgaris (Barbarea vulgaris L.)

Seed germination of Barbarea vulgaris (Barbarea vulgaris L.) was determined on the 7th day. The dependence of germination, growth of shoots and roots of seedlings on the concentration of oil pollution in the substrate is shown in table 1.

Table 1. The influence of the concentration of oil pollution in the substrate on the germination of Barbarea vulgaris (Barbarea vulgaris L.).

| Oil concentration, wt ppm | 0      | 500    | 1000   | 2000   | 3000   |
|---------------------------|--------|--------|--------|--------|--------|
| Germination %, M ± m      | 93.3 ± 0.0 | 90.0 ± 3.3 | 86.7 ± 0.0 | 80.0 ± 0.0 | 76.7 ± 3.3 |
| Length of scion, mm       | 4.1 ± 0.1 | 3.7 ± 0.4 | 3.5 ± 0.9 | 3.2 ± 1.4 | 2.7 ± 0.3 |
| Length of plant root, mm  | 9.1 ± 1.6 | 8.4 ± 1.4 | 7.3 ± 0.1 | 4.8 ± 3.1 | 8.3 ± 1.9 |

As can be seen from the results, oil pollution contributed to a decrease in seed germination of Barbarea vulgaris by 16.6%. Oil pollution has had a significant impact on root growth. The inhibition of root growth was proportional to the dose of the pollutant (except for 3000 ppm). The root length decreased by 20% at an oil concentration of 1000 ppm and 2 times at an oil concentration of 2000 ppm. A significant decrease in shoot length (by 20-33%) was observed when grown on a substrate containing 2000 ppm and 3000 ppm of oil, respectively.

Barbarea vulgaris is susceptible to contamination of the substrate with oil with an oil concentration of more than 1000-2000 ppm: seed germination, root length and shoot height of seedlings decrease in comparison with the control sample.

7. The research into the seeds of white mustard (Sinapis alba L.)

Seed germination of white mustard (Sinapis alba L.) was determined on the 6th day. The dependence of germination, growth rate of shoots and roots of seedlings on the concentration of oil pollution in the substrate is shown in table 2.

Table 2. The influence of the concentration of oil pollution in the substrate on the germination of white mustard (Sinapis alba L.).

| Oil concentration, wt ppm | 0      | 500    | 1000   | 2000   | 3000   |
|---------------------------|--------|--------|--------|--------|--------|
| Germination %, M ± m      | 93.3 ± 0.0 | 83.3 ± 3.3 | 50.0 ± 3.3 | 56.7 ± 3.3 | 46.7 ± 0.0 |
| Length of scion, mm       | 1.1 ± 0.2 | 1.0 ± 0.1 | 1.0 ± 0.0 | 2.0 ± 1.4 | 4.0 ± 1.4 |
| Length of plant root, mm  | 1.6 ± 0.1 | 1.4 ± 0.0 | 1.6 ± 0.5 | 3.0 ± 1.4 | 5.0 ± 1.4 |

As can be seen from the results, with an increase in the concentration of oil pollution in the substrate, seed germination of white mustard (Sinapis alba L.) decreased by 46.6%. It is shown that oil pollution had a more significant effect on the growth of the white mustard (Sinapis alba L.) root. The inhibition of root growth was proportional to the dose of the pollutant. The root length decreased by 31% at an oil concentration of 1000 ppm and by 39% at an oil concentration of 2000-3000 ppm. The shoot length remained practically unchanged.

White mustard (Sinapis alba L.) is sensitive to contamination of the substrate with oil with an oil concentration of more than 1000 ppm: seed germination decreases, the length of seedling roots compared to the control sample, while the length of the shoot does not change.
8. The research on trifolium repens (Trifolium repens L.) seeds
Seed germination of trifolium repens (Trifolium repens L.) was determined on the 7th day. The dependence of germination, growth rate of shoots and roots of seedlings on the concentration of oil pollution in the substrate is shown in table 3.

Table 3. The influence of the concentration of oil pollution in the substrate on the germination of trifolium repens (Trifolium repens L.).

| Oil concentration, wt ppm | 0     | 500   | 1000  | 2000  | 3000  |
|--------------------------|-------|-------|-------|-------|-------|
| Germination %, M ± m     | 56.7 ± 3.3 | 53.3 ± 0.0 | 63.3 ± 3.3 | 60.0 ± 6.6 | 73.3 ± 0.0 |
| Length of scion, mm      | 5.6 ± 0.3 | 4.0 ± 0.2 | 3.8 ± 0.7 | 3.8 ± 0.3 | 3.6 ± 0.6 |
| Length of plant root, mm | 3.4 ± 1.1 | 3.2 ± 1.1 | 3.0 ± 0.4 | 2.3 ± 0.4 | 4.1 ± 0.4 |
| Dry basis, mg            | 118.1 ± 0.3 | 102.5 ± 0.6 | 91.9 ± 1.3 | 84.6 ± 0.8 | 116.7 ± 0.0 |

As can be seen from the results, the germination of seeds of trifolium repens (Trifolium repens L.) slightly increased in comparison with the control sample, but it did not depend on the content of oil products in the soil. It is shown that an increase in the concentration of oil pollution in the substrate had a more significant effect on the growth of the trifolium repens (Trifolium repens L.) root. The inhibition of root growth was proportional to the dose of the pollutant (except for 3000 ppm). The root length decreased by 32% at an oil concentration of 2000 ppm. Shoot length decreased regularly by 28-35% in comparison with the control sample with an increase in the concentration of oil in the substrate. The mass of seedlings also decreased with an increase in the concentration of oil in the substrate, except for 3000 ppm.

Trifolium repens (Trifolium repens L.) is sensitive to substrate contamination with oil with an oil concentration of more than 500 ppm: seed germination, the length of roots and shoots of seedlings decrease in comparison with the control sample, and the dry weight of seedlings. Clover belongs to the Fabaceae family, whose representatives, during seed germination, begin to colonize the root system with bacteria of the genus Rhizobium. This process contributes to the inhibition of seedling growth in the early stages. The presence of oil in the soil probably slows down the colonization process; therefore, growth and germination capacity increase when the accumulation of oil products exceeds 3000 ppm.

9. The research on cress (Lepidium sativum L.) seeds
The germination of seeds of the bedbug, or cress (Lepidium sativum L.), was determined on the 5th day. The dependence of germination, growth rate of shoots and roots of seedlings on the concentration of oil pollution in the substrate is shown in table 4.

Table 4. The influence of the concentration of oil pollution in the substrate on germination cress (Lepidium sativum L.).

| Oil concentration, wt ppm | 0     | 500   | 1000  | 2000  | 3000  |
|--------------------------|-------|-------|-------|-------|-------|
| Germination %, M ± m     | 82.5 ± 3.3 | 75.0 ± 0.0 | 75.0 ± 0.0 | 75.0 ± 0.0 | 75.0 ± 0.0 |
| Length of scion, mm      | 5.0 ± 0.1 | 3.5 ± 0.8 | 3.4 ± 0.4 | 3.0 ± 0.8 | 2.6 ± 0.0 |
| Length of plant root, mm | 4.9 ± 1.0 | 4.3 ± 0.5 | 3.9 ± 0.4 | 2.7 ± 0.1 | 5.2 ± 0.0 |
| Dry basis, mg            | 93.5 ± 0.0 | 101.3 ± 1.1 | 105.9 ± 0.7 | 118.2 ± 0.5 | 124.2 ± 0.7 |

As can be seen from the results, the germination rate of cress (Lepidium sativum L.) seeds slightly decreased in comparison with the control sample, but it did not depend on the content of oil products in the soil. It is shown that oil pollution had a significant impact on the growth of cress (Lepidium sativum L.) root. The inhibition of root growth was proportional to the dose of the pollutant (except for 3000 ppm). The root length decreased by 20-45% at an oil concentration of 1000-2000 ppm, respectively, and corresponded to the control sample at an oil concentration of 3000 ppm. The shoot length decreased regularly by 29-47% compared to the control sample with an increase in the concentration of oil in the soil.
substrate from 500 to 3000 ppm. The mass of seedlings increased by 9-31% compared to the control sample with an increase in the concentration of oil in the substrate from 500 to 3000 ppm.

Cress (*Lepidium sativum* L.) is susceptible to contamination of the substrate with oil with an oil concentration of more than 500 ppm: the germination of seeds, the length of roots and shoots of seedlings are reduced in comparison with the control sample. With an increase in the concentration of oil pollution in the substrate, the dry mass of cress (*Lepidium sativum* L.) seedlings increases, so the plants can show resistance to oil pollution of the soil.

10. Conclusions
From the data obtained on four experimental studies, it is possible to distinguish the classification of plants according to the degree of resistance to oil pollution of the soil, which makes it possible to recommend the use of resistant plants for cultivation as green plantings – cress and trifoilum repens (*Trifolium repens* L.). The selected plants retain the ability to grow under contaminated conditions and have the effect of phytoremediation. At the same time, during the analysis of seed germination in trifolium repens (*Trifolium repens* L.), a paradoxical phenomenon was found – an increase in seedling growth at the maximum oil concentration. It is concluded that trifoilum repens (*Trifolium repens* L.) can be promising for use as a phytoremediant at concentrations of oil products in the soil over 3000 ppm.

The results of studies aimed at identifying the plant species most suitable for using it as a phytoremediant indicate that the most effective is cress (*Lepidium sativum* L.), which among the studied plants is less susceptible to the toxic effects of oil pollution and is most adapted to growth. on oil-contaminated soils. It has a developed root system, the highest seedling height and high seed germination on oil-contaminated soil samples of various concentrations. This germination rate can be considered acceptable for the use of cress (*Lepidium sativum* L.) as a remediation agent. The mass of cress (*Lepidium sativum* L.) increases with increasing oil concentration. This phenomenon shows that the plant's resistance to the pollutant is high.

References
[1] Ministry of Natural Resources and Environment of the Russian Federation Retrieved from: http://www.mnr.gov.ru/docs/open_ministry/report/?special_version=Y
[2] Petuhova G A 2000 New in ecology and life safety: collection of abstracts of the international environmental congress (St. Petersburg: Research Institute of Mechanics) 334
[3] Muhammad H S, Shafaqat A, Saddam H, Muhammad K, Muhammad S C, Shoaib A, Muhammad A, Muhammad R, Nada H. A, Saad A and Mohamed M. A 2020 *Fundamental and Applied Research* for the Effective Deployment of Phytoremediation 9(4) 496
[4] Newman L A, Reynolds C M 2004 *Current Opinion in Biotechnology* 225–30
[5] Odegova T F, Balandina A V, Burlakova E M, Zlotnikov K M, Zlotnikov A K and Kazakov A V 2008 *Pat. of the Russian Federation* No 2421291C2 appl 27.01.2008, publ. 20.06.2011
[6] Sakson V M, Kuznetsov S A, Bojkova I V, Novikova I I *Pat. of the Russian Federation* No 2191643C1 appl. 09.07.2001, publ. 27.10.2002
[7] Kosiorek M and Wyszkowski M 2020 *International Journal of Phytoremediation* 23(7) 669-83
[8] Tutarashvili K G, Nefed’eva E E 2020 *Modern Scientific Research: Problems And Solutions*, ed N A Krasnova (St. Petersburg: Scientific public organization Professional Science) 37-45