Assessment of the Phytotoxicity of Soils on Main Streets of Voronezh City

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Abstract. This research looks at the results of a study assessment of phytotoxicity soils of the main streets of the city Voronezh. The experiments were performed under ecologo-analitic laboratory Voronezh State University conditions over a 21-day evaluation period. The phytotoxic effect germination was analyzed on *Avena sativa* L. seeds, germination energy, morphological parameters of seedlings, and plant biomass. The research soil samples had both an inhibitory and stimulating effect on the growth of the above-ground part of the seedlings and roots *Avena sativa*. The sections of main streets with increased phytotoxicity soils were revealed. It is recommended to carry out measures to reduce the phytotoxicity of urban soils.

1. Introduction

Soils hold a specific place in ecosystems and carry out a huge number of functions, the most important of which – environmental. Growth of the cities leads to reduction of a share of "live" soils and increase in a share of the broken lands that creates threat to health and human life in the urbanized environment. City soils concern to group of the anthropogenic transformed soils – urbanozem. Existence in the soil of pollutants and toxins suppresses growth and development of plants. City soils are characterized by property of phytotoxicity [1].

In Russia and other countries the study of environmental condition soils on the basis bioassay methods are very relevant and widely used to assess toxicity in agricultural [2-5] and urban [6] soils. Phytotesting has been relatively recently used in the environmental field to assess the quality of the environment in natural environments (water, soil). Methodical recommendations on the use of higher plant seeds in phytotesting have been developed [1,7]. The thresholds of phytotoxicity pollutants for various test plants are established [8,9].

The main contribution to the atmosphere pollution and soils of Voronezh is made by vehicles, the emissions make up more than 85% of the total amount pollutants. An inevitable factor is contamination with heavy metals, which easily accumulate and reduce the stability of the vegetation cover of urbanized areas. In the most depressed state is the vegetation cover of highways, streets with intensive traffic and boulevards the central part of the city.

The aim of this work is to study the assessment phytotoxicity of soils in the main streets of Voronezh. Objectives of the study: to conduct a laboratory study of the phytotoxicity urban soils; to

assess the phytotoxic effect in terms of the germination Avena sativa L. seeds, the germination energy and the morphological parameters of *Avena sativa* seedlings, the biomass (green mass) of the plants; identify areas of main streets with increased phytotoxicity of soils.

2. Equipment and devices used in studies

Zonal soil is Voronezh black soil, which occupies lofty upland areas of the Voronezh. Gray forest-steppe soils are developed where previously there was an array of oak. Sod-forest sandy soils and meadow-black soil remained within the limits of the Voronezh on a very limited area and everywhere have undergone anthropogenic changes. The natural soil is in the central part of the city almost did not survive intact. Only in gardens, parks, and large yards presents less transformed anthropogenic transformed soils.

Long-term studies based on the analytical laboratory of Voronezh State University show that, the central part of Voronezh, Pb content exceeds the background level by 1.3-26 times and MAC (normative approved in law in Russia) (32.0 mg/kg) by 1.3-6.4 times. The Cd content exceeds the background values of 1.3-3.3, but does not exceed the MAC (0.5 mg / kg). Approximately 90% of the cases, the Zn content exceeds the background and 1.3-2.3 times the MAC (23.0% mg/kg). In the upper horizons of the urban soils Voronezh, the Cu content varies widely - from 6.0 to 284.0 mg / kg and exceeds the MAC values (3.0 mg/kg) by a factor of 3-95. In general, pollution of oil products, gross and mobile forms of heavy metals, Voronezh's urban areas are classified as low, medium and high pollution [10].

Phytotesting as a method of environmental monitoring is an integral method of analysis, which provides information on the toxicity of various media and substances. The method is based on the sensitivity of plants to exogenous chemical effects, which affects the growth and morphological characteristics. This method is accessible and simple for experiments, reproducible, reliable, economical and objective [1, 11].

To study the phytotoxicity of Voronezh soils, samples were taken in the middle of summer 2015 and 2016. In 10 points of main streets on both sides. At each point, two samples were taken at a distance of 1 and 5 m from the roadway. Sampling points of soils on the main street Moskovskijprospekt, public transport stops: «TorgovyjCentr» No. 1 (samples 1-4), «PamyatnikSlavy» No. 2 (samples 5-8), «Avtovokzal» No. 3 (samples 9-12), square «Politekhnicheskij» No. 4 (samples 13-16), «ProspektTruda» No. 5 (samples 17-20). The sampling points of soils on the main street of 9 Yanvarya are located at the intersection with the following streets: F. EHngel'sa No. 6 (samples 21-24), Kol'covskaya No. 7 (samples 25-28), ProspektTruda No. 8 (samples 29-32), Mashinostroiteley No. 9 (samples 33-36), Krasnodonskaya No. 10 (samples of 37- 40). As a background (control), the soil (samples 41, 42) specially protected natural area of the suburban area was selected. A total of 42 soil samples were taken in the study in duplicate.

Avena sativa L. was used as a test culture. Intact seeds of *Avena sativa* were selected for the experiments, whose germination capacity was not less than 95%. Phytotesting was carried out on the basis of the ecological-analytical laboratory of the Voronezh State University. Seeds of *Avena sativa* were sown in special containers with soil samples. Observations lasted 21 days. The percentage of seed germination was noted. Germination was considered as a percentage of germinating seeds in experimental containers, with respect to control. On the 10th day, the morphometric parameters of the seedlings were measured: the height and green mass of the aerial part, the length and the living mass of the root.

Phytotoxic effect (PE) can be calculated using different approaches. More commonly used indicators of germination of seeds and plant biomass. Phytotoxic effect of PE (%) is calculated by the formula:

$$PE = \frac{M_o - M_x}{M_o} \quad 100\% \qquad (1)$$

whereMo – is the mass of the control plant (or all plants per container with a control soil sample); Mx – is the mass of the plant (s) grown on a phytotoxic soil.

3. Results and discussion

It was revealed that on 8 soil samples germination of seeds *Avena sativa* was equal to or greater (90-100%) than the control value. On 11 soil samples, seed germination was 70-89%. The lowest percentage of seed germination (less than 50%) was recorded on 13 of the studied soil samples, which corresponded to the following items: public transport stops «TorgovyjCentr» No. 1, square «Politekhnicheskij» No. 4, «ProspektTruda» No. 5; the intersection of the streets of the 9 Yanvarya with F. EHngel'sa No. 6, ProspektTruda No. 8 and Mashinostroiteley No. 9.

In some samples, the phenomenon of hormesis (Figure 1) was noted - the improvement of seed germination, growth and survival of test plants at low concentrations of pollutants. The maximum germination of seeds was noted on soil samples from points: «Avtovokzal» No. 3 (samples 9-12), square «Politekhnicheskij» No. 4.

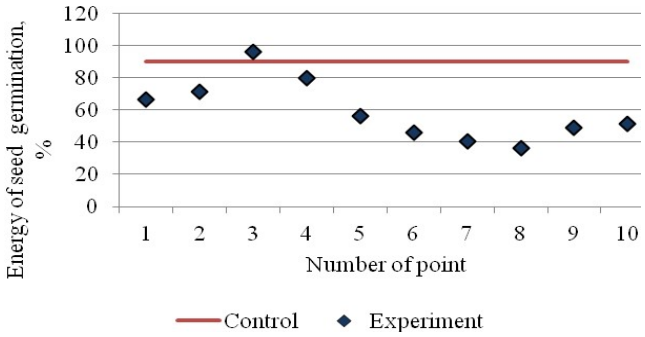

Figure 1 – Energy of seed germination *Avena sativa* on the 4th day (2015)

For 13 soil samples, the percentage of seed germination *Avena sativa* is equal to or greater than the control (90-100%). In 16 samples, the proportion of germinating seeds was 70-89%. The lowest percentage of seed germination (less than 50%) is noted on soil samples of the following point: «TorgovyjCentr» No. 1, «ProspektTruda» No. 5, the intersection of the streets of the 9 Yanvarya with F. EHngel'sa No. 6 and Mashinostroiteley No. 9 (figure 2).

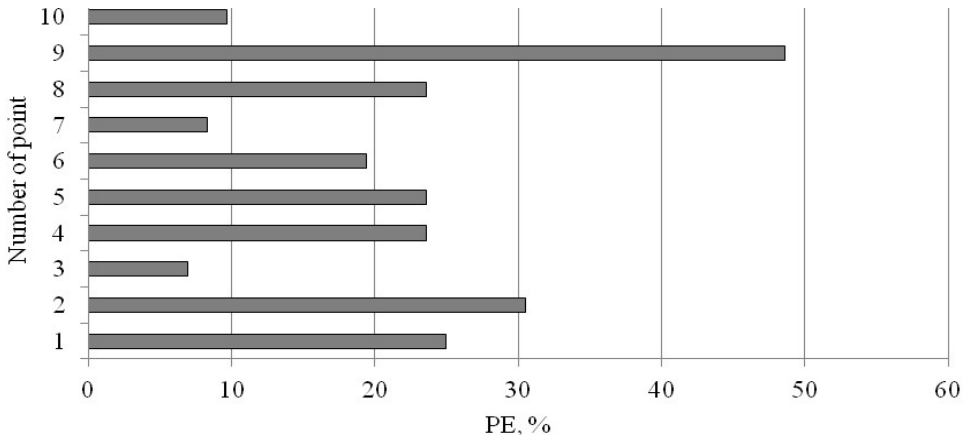

Figure 2 – Phytotoxic effect on the germination of *Avena sativa* seeds(2016)

Considering the values obtained in the control soil samples (table 1), a comparative analysis of the results of the study.

Table 1–Morphometric parameters of *Avena sativa* seedlings (on control soil samples 41, 42) 2015, 2016

Germination, %	Above-groundpart		Roots	
	2015			
	height, см	weight, g	length, см	weight, g
	$X_{average} \pm m_x$	$X_{average} \pm m_x$	$X_{average} \pm m_x$	$X_{average} \pm m_x$
90	17±0.56	0.84±0.03	8.65±0.45	0.55±0.01
	2016			
	16.5±0.53	1.01±0.08	13.0±0.60	0.58±0.03

The investigated soil samples had both an inhibitory and stimulating effect on the growth of the above-ground part and the root system of *Avena sativa* seedlings (Fig. 3).

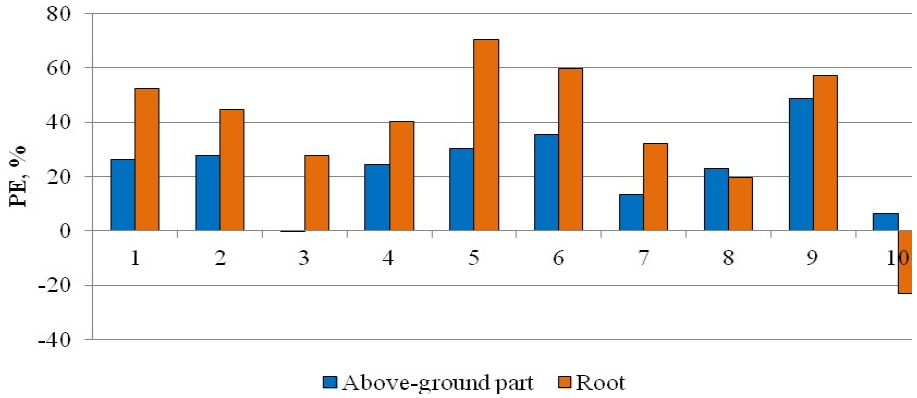

Figure 3 – Phytotoxic effect on biomass of Avena sativa seedlings (2016)

The most sensitive organ of plants to the environmental conditions of growth are the roots. Therefore, along the length of the roots, one can also judge the phytotoxicity of the soil samples under study.

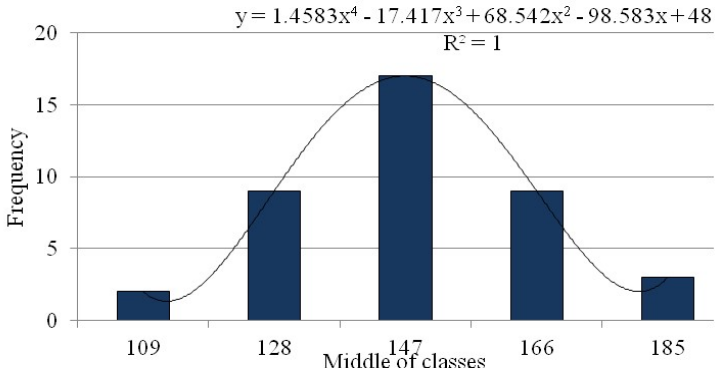

Figure 4 - The length distribution curve (mm) of the root system of *Avena sativa* seedlings (2016)

The distribution of values of the root length index can be described by the equation of a polynomial curve of the fourth degree. The distribution of the length index of the aboveground part of plants is characterized by a polynomial curve of the third degree. These models are considered adequate, because the criterion of adequacy (approximation) R^2>0.95 (Fig. 4,5).

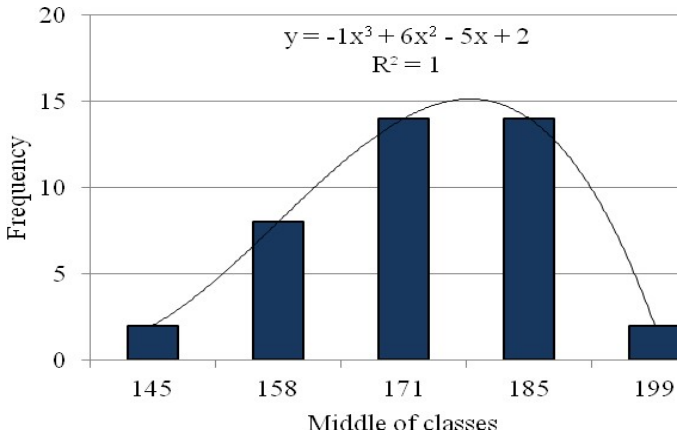

Figure 5 – The height distribution curve (mm) of the above-ground part of the *Avena sativa* seedlings (2016)

The longest root length of Avena sativa seedlings was formed on soil samples of the following points: «TorgovyjCentr» No. 1, «Avtovokzal» No. 3, square «Politekhnicheskij» No. 4, «ProspektTruda» No. 5. The maximum height of seedlings was noted for soil samples selected in the vicinity of public transport stops «TorgovyjCentr» No. 1, «PamyatnikSlavy» No. 2, «Avtovokzal» No. 3, the intersection of the street 9 Yanvarya with F. EHngel'sa No. 6 and ProspektTruda No. 8.

The results of phytotesting of soil samples confirmed technogenic contamination of the soils the main streets of Voronezh.

4. Conclusions

In general, most *Avena sativa* seedlings stimulated the growth of the root system. On average, 70% of the seedlings grown on soils from different points showed a significant increase in the length of the root system by 20-25% compared to the control. The same trend is observed for the mass of the roots. In 55% of the seedlings, the mass of the root system exceeds the values of the control sample. In 62.5% of the seedlings, the growth of the above-ground part was inhibited. The data obtained are consistent with the results of studies phytotoxicity soils in Voronezh in 2002-2009. In experiments with *Triticumaestivum* L. and *Raphanussativus* L. The study shows that the more active formation of the root system in conditions of pollution occurs due to the reduction of the biomass of the aerial organs and is considered as the forced need of the seedling to strengthen the root capacity and protect the vulnerable assimilation system of the aerial part from toxicity polluting substances.

The sections of the main streets of Voronezh with increased phytotoxicity of soils are determined: the stop public transport «ProspektTruda», the intersection of the street 9 Yanvarya with F. E ngel'sa street, Krasnodonskayastreet, Kol'covskaya street and ProspektTruda street. Avena sativa seedlings grown on the soils of the indicated points showed maximum inhibition of the above-ground part of the plant and an increase in the length and mass of the root system.

The results should be taken into account when planning the works on the greening of the main streets of Voronezh. The creation of sustainable lawns and flower beds is possible only after carrying out measures to reduce the phytotoxicity of urban soils.

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