The effect of natural salt of various concentrations on the chernozem chemical properties

N L Kurachenko¹, O A Ulyanova, O A Vlasenko and E Yu Casanova
Krasnoyarsk State Agrarian University, 90 Mira Av., Krasnoyarsk, 660049 Russia

¹E-mail: kurachenko@mail.ru

Abstract. In the laboratory experiment, the effect of natural salt with herbicidal activity on the chemical properties of the soil is evaluated. To study the mechanism of action of natural salt with a concentration of 1, 5, 10, 15, and 20% on the plant-soil system and the change in chemical state, untreated natural brines of the Troitsk deposit in the Krasnoyarsk Territory were used. Studies have found that the use of natural salt as a herbicide determined alkalinization of the soil by 0.2 - 0.7 units pH while maintaining a neutral reaction of the soil solution, increasing the amount of exchange bases by 1.0 mmol / 100g, changing the composition of the aqueous extract. The maximum amount of toxic salts with a predominance of NaCl in the aqueous extract was found in the case of a 5% concentration of natural salt. A salt concentration of 5 and 10% determined strong salinization of the soil, 15 and 20% - strong. The concentration of natural salt of 5% and above determined the possibility of further soil alkalinization.

1. Introduction
Weeds, being a constant component of anthropogenic ecosystems, significantly reduce the level of crop productivity and affect the efficiency of agricultural practices [1,2]. According to [3], despite the emergence of chemical herbicides, weeds and other undesirable vegetation remain a serious problem in crop production. This is due to the emergence of weed plants forms resistant to herbicides and the prohibition of the chemicals use near housing and in organic farming. In this regard, studies aimed at searching for natural compounds with herbicidal activity and studying their effect on soil and plants are of interest. Among modern bio-rational plant protection products, weed control preparations are the worst represented [4].

The possibilities of using non-traditional herbicides of natural inorganic origin in agriculture, road construction and in the operation of railways should be based on studying the mechanism of transport of the herbicide in the plant-soil system and analysing their effect and aftereffect on soil properties and regimes. The purpose of the study is to assess the impact of natural salt with herbicidal activity on the chemical state of the soil.

2. Objects of the research
The studies were conducted in a laboratory experiment at the Department of Soil Science and Agrochemistry of the Krasnoyarsk State Agrarian University. To study the mechanism of action of natural salt of various concentrations on the soil-plant system and the change in the chemical state of the soil under the influence of components entering the soil, an experiment was carried out in which untreated natural brines of the Troitsky deposit in the Krasnoyarsk Territory were used. The Troitsk deposit, geographically located in the Krasnoyarsk Territory, has proven reserves of halite mineral of...
about 1 billion tons. The untreated natural brines of this field in their composition contain in g/l: sodium - 77.07; magnesium - 0.49; iron - 36.79; calcium - 2.56; potassium - 2.36; chlorides - 131.00; sulphates - 1.51. Laboratory experiment was carried out in vessels with a capacity of 1 litre in 3-fold repetition. The soil taken for the experiment is leached chernozem of clay granulometric composition.

In the experiment, the concentrations of natural salt of 1, 5, 10, 15, and 20% obtained by sequential dilution of the initial base brine were used. Diluted to the above concentrations with natural salt, seedlings of common wild oat were sprayed once (Avena fatua L., Family Poaceae). As a control option, tap water was used to spray the weed. Plants watering was carried out 3 times a week with tap water in an amount of 50 ml. After complete inhibition of the plants of wild oat by a natural herbicide for 4 days, the chemical composition of the soil was determined in the soil.

3. Research methods

In soil samples selected in 3 replicates, the following was determined: humus by the Tyurin method [5], the reaction of the soil solution by the ionometric method [GOST 26423-85]; the amount of exchange bases according to the Kappen method [GOST 27821-88]; the content of cations and anions of the aqueous extract was determined in the system of capillary electrophoresis Kapel-105M. The obtained research results were processed by the method of variance and correlation analysis [6].

4. The results of the study

One of the most important indicators of the chemical composition of soils is the humus content as a result of the humification of organic substances. The soil taken for laboratory experiments was characterized by an average humus content, which confirms its belonging to low-humus medium-power leached chernozems. The humus content in the soil of the control variant and under the conditions of using natural salt as a herbicide varied from 5.2 to 5.4% and did not significantly differ (table 1).

| Option                  | Humus, % | $pH_{H_2O}$ | Total exchangeable bases, mmol / 100g |
|-------------------------|----------|-------------|--------------------------------------|
| Control - no tillage    | 5.2      | 6.6         | 47.0                                 |
| Natural salt 1 %        | 5.3      | 6.8         | 47.3                                 |
| Natural salt 5 %        | 5.4      | 7.0         | 47.0                                 |
| Natural salt 10 %       | 5.4      | 7.0         | 47.3                                 |
| Natural salt 15 %       | 5.4      | 7.2         | 47.8                                 |
| Natural salt 20 %       | 5.2      | 7.3         | 48.0                                 |
| $HCP_{05}$              |          | F<sub>T</sub> | 0.1                                  |

The leached black soil was characterized by neutral reaction of soil solution ($pH_{H_2O}$ 6.6) with fluctuations in the range of 6.6 to 7.3. Alkalization of the soil while maintaining a neutral reaction compared to the control variant amounted to 0.2 and 0.7 pH units. The maximum value of the reaction medium in the aqueous extract after a single use natural salt is marked in the case of 20% concentration of natural herbicide. Similar results were obtained by E. M. Nikiforova et al [7] in the case of application of anti-icing agents on highways, sidewalks and in the yards of residential areas. According to the authors, the systematic application of technical salt with sand and fine gravel contributed to basified soil relative to the background of 2.3 pH units. Migration in the soil sodium and its adsorption by soil colloids contributed to the increase of the charge and the degree of dispersion of colloidal particles, which is reflected in the value of the amount of exchange bases.
Previously, it was found that the herbicidal treatment of plants with natural salt was reflected in the change in the fractional composition of structural aggregates. The increase in the proportion of fine aggregates < 0.25 mm by 2-5% compared to the control indicates an increase in dispersion of soil colloids under the influence of exchangeable sodium [8]. A remarkably high amount of exchange bases, due to clay particle size distribution naturally increased with increasing concentration of natural salt from 47.0 to 48.0 mmol / 100g.

The release of residual amounts of natural herbicide into the soil at the time of spraying and wilting of plants, as well as its concentration determined an ambiguous change in chemical properties, which is confirmed by the manifestation of correlation between the salt solution concentration and the studied parameters (figure 1). It was found that the concentration of the solution did not affect the humus content in the soil (r = 0.19). It determined alkalization of the chernozem at 81% and had a strong direct relationship with the amount of exchange bases (r = 0.90).

Figure 1. The relationship between the concentration of natural salt and chemical indicators of leached chernozem.
Chernozems belong to the non-saline soil because of the dense residue in their profile does not exceed 0.1 % [9,10]. Analysis of the aqueous extract shows that the soil of the control variant among cations and anions is dominated by Ca$^{2+}$ and Cl$^-$. Their concentration in the soil solution does not exceed 0.66 mmol/100 g. The application of natural salt as a herbicide significantly changes the composition of the aqueous extract of leached chernozem, increasing the concentration of Na$^+$ at 3-62; Mg$^{2+}$ - 2-8; Ca$^{2+}$ - 2-7; Cl$^-$ - 3-49; SO$_4^{2-}$ - 2-5 times in comparison with the control variant. For judgments about the qualitative composition of salts water extract analysis results are converted to hypothetical (conditional) salts (table.2). The results showed that the main salts present in the soil solution are CaSO$_4$, NaCl, MgCl$_2$ and CaCl$_2$. The last three salts are toxic to plants. Amount of toxic salts in the soil of the control variant is less than 0.4 %. The application of natural salt as a herbicide identified increasing quantities of toxic salts to 1-21 %. The maximum amount of toxic salts of high-water extraction NaCl installed in case of 5 % concentration of natural salt. Sodium chloride is the main component of the brine deposits of the Troitsk deposit, possesses herbicidal activity and migration ability at a solution concentration greater than 5 % [11]. Such trends caused a substantial decrease in soil moisture in the experiment at the concentration level of natural herbicide. We found that the minimum soil moisture (10 %) and water evaporation during drying not exceeding of 4 gr. are marked at the variant with concentration of salt 5% that is the lower limit of the beginning of the death of weeds in the experiment.

**Table 2.** Salts qualitative composition in leached chernozem after processing the wild oat with natural salt of various concentrations.

| Option          | Salt       | Mmol / 100g | %   | Total salt, % |
|-----------------|------------|-------------|-----|---------------|
|                 |            |             | non toxic | toxic        |
| Control - no    | CaSO$_4$   | 0.02        | 0.014 |               |
| tillage         | NaCl       | 0.42        | 0.246 | 0.014         | 0.429 |
|                 | MgCl$_2$   | 0.22        | 0.105 |               |
|                 | CaCl$_2$   | 0.14        | 0.078 |               |
|                 | CaSO$_4$   | 0.14        | 0.095 |               |
| Natural salt    | NaCl       | 1.16        | 0.679 | 0.095         | 1.274 |
| 1 %             | MgCl$_2$   | 0.34        | 0.162 |               |
|                 | CaCl$_2$   | 0.78        | 0.433 |               |
|                 | CaSO$_4$   | 0.36        | 0.245 |               |
| Natural salt    | NaCl       | 26.02       | 15.222 | 0.245         | 21.118 |
| 5 %             | MgCl$_2$   | 1.68        | 0.801 |               |
|                 | CaCl$_2$   | 9.18        | 5.095 |               |
|                 | CaSO$_4$   | 0.18        | 0.123 |               |
| Natural salt    | NaCl       | 10.70       | 6.260 | 0.123         | 9.931 |
| 10 %            | MgCl$_2$   | 1.04        | 0.496 |               |
|                 | CaCl$_2$   | 5.72        | 3.175 |               |
|                 | CaSO$_4$   | 0.16        | 0.109 |               |
| Natural salt    | NaCl       | 7.90        | 4.622 | 0.109         | 7.596 |
| 15 %            | MgCl$_2$   | 0.88        | 0.420 |               |
|                 | CaCl$_2$   | 4.62        | 2.564 |               |
|                 | CaSO$_4$   | 0.20        | 0.136 |               |
| Natural salt    | NaCl       | 6.46        | 3.779 | 0.136         | 6.427 |
| 20 %            | MgCl$_2$   | 0.78        | 0.372 |               |
|                 | CaCl$_2$   | 4.10        | 2.276 |               |

The same amount of salts may be present in different soils, but depending on their composition, the soils will have different degrees of salinity level, which is due to the unequal toxicity of the salts present.
to plants. Assessment of the degree of salinity by the presence of toxic salt ions in the soil based on the “cumulative effect” showed that the soil of the control variant is classified as non-saline. When using a natural salt of 1% concentration as a herbicide, the soil is characterized by medium salinity. The salt concentration of 5 and 10% determined a strong salinization of the soil, 15 and 20% - strong. Considering the fact that Na⁺ dominates among the cations in the chemical composition of natural salt, the possibility of soil salinization was calculated. It is shown that in the soil of the control variant and with the use of 1% salt concentration it is excluded. Concentration of natural salt of 5% and higher determined the possibility of soil salinization.

Thus, the results of a laboratory experiment using salt with a concentration of 1 to 20% as a herbicide indicate a significant change in the physicochemical properties of leached chernozem. A single spraying of the growing wild oatmeal with a solution of salt with a concentration of 5 to 20% significantly changes the composition of the water extract, determining very strongly the strong salinization of the soil and the possibility of its further salinization.

Acknowledgments
The study was carried out with the financial support of the Russian Foundation for Basic Research (RFBR) in the framework of the scientific project No. 20-416-242903 p._Yenisei Siberia.

References
[1] Belousov A A, Belousova E N, Bopp V L, Litvinova V S and Antonova T S 2019 Nitrogen transformation and urease activity when using herbicides the Bulletin of KrasGAU 11 9-15
[2] Bopp V L and Danilov M E 2020 Lupine narrow-leaved: the effect of herbicides and fertilizers on the productivity of green mass the Bulletin of KrasGAU 5 73-79
[3] Berestetskiy A O 2017 Prospects for the development of biological and biorational herbicides Plant Protection News 1 (91) 5-12
[4] Duke S O, Owens D K and Dayan F E 2014 The Growing Need for Biochemical Bioherbicides Biopesticides: State of the Art and Future Opportunities”ACS Symposium Series, American Chemical Society 117 31- 43
[5] Arinushkina E V 1979 Guidance on Chemical Analysis of Soils (Moscow: Publishing House of Moscow State University)
[6] Dospekhov B A 2014 The Methodology of Field Experience (with the Basics of Statistical Processing of Research Results) (Moscow: Alliance)
[7] Nikiforova E M, Kosheleva N E and Khaibrakhmanov T S 2016 Ecological consequences of using deicing reagents for soils of the eastern district of Moscow Vestnik Moskovskogo Universiteta. Seria 5. Geografiya 3 40-49
[8] Kurachenko N L, Ulyanova O A, Vlasenko O A and Casanova E Yu 2020 The effect of natural salt of various concentrations on the agrophysical state of the soil in a model experiment the Bulletin of KrasGAU 6
[9] Bugakov P S and Chuprova V V 1995 Agronomic Characteristics of the Soils of the Agricultural Zone of the Krasnoyarsk Territory (Krasnoyarsk: KrasGAU)
[10] Khmelyov V A and Tanasienko A A 2009 Land Resources of the Novosibirsk Region and Ways of Their Rational Use (Novosibirsk: Publishing House of the SB RAS)
[11] Ul’yanov A A, Kurachenko N L and Vlasenko O A 2020 Justification of the possibility of using natural brines as a herbicide Agricultural Landscapes, Their Stability and Developmental Features ed A I Trubilin (Krasnodar: Kuban SAU) pp74-75