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The use of electrophysical indicators during the cultivation of strawberries on drip irrigation

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Abstract. Electrophysical research methods are widely used in countries with developed agricultural production for the purpose of soil monitoring and surveys. One of these methods of research is determining the electrical conductivity of the soil. Because with the help of this indicator, it is relevant to clarify the boundaries of soil differences, which makes it possible to use it in precision agriculture. Thus, the purpose of the article is to compare the changes in the electrophysical parameters of typical chernozem under different fertilization systems under conditions of drip irrigation. In order to carry out the analysis, individual soil samples were taken for each year of research in the period 2018-2020 in the spring (May) before the start of strawberry flowering. From the selected and air-dried soil samples using the quarting method, average mixed samples were selected for analysis. It was concluded that electrophysical indicators undergo changes according to the depth of sampling, which is related to the assimilation of useful substances from the soil by plants and fertilization mechanisms and correlates to a significant extent with the acid-alkaline indicators of the soil. A three-year study (2018-2020) of the influence of different fertilization systems under drip irrigation conditions on the electrophysical parameters of typical chernozem during the cultivation of garden strawberries was conducted. It was established that the greatest changes in electrophysical indicators (electrical conductivity, general mineralization, salinity) of typical chernozem occur from the ridge part to a depth of 20-30 cm. The difference in the obtained values of electrophysical indicators between variants of different fertilization of typical chernozem (control, mineral system, organo-mineral system, organic system), as well as during years of research

Keywords: typical chernozem, electrophysical parameters, drip irrigation, fertilization

INTRODUCTION

In countries with developed agricultural production, electrophysical research methods are widely used for soil surveys and monitoring. One of them is the determination of the electrical conductivity of the soil [1; 2].

With the help of this indicator, it is convenient to specify the boundaries of soil differences, which makes it possible to use it in precision agriculture [3]. The electrical conductivity indicator is a kind of indicator of changes occurring in the soil, because it is closely correlated with many indicators of fertility.

Electrical conductivity of the soil is the ability of the soil to conduct an electric current, expressed in siemens per unit area (S/m – siemens per meter, or μS/cm – microsiemens per centimeter). Electrical conductivity is an indicator that responds sensitively to changes in soil moisture and temperature, grain size composition, cation exchange capacity, salinity, content of exchangeable cations, content of organic matter, etc.

The electrical conductivity of the soil solution characterizes the content of salts in it, which directly affect the growth and development of plants, which is an important aspect of soil quality. Therefore, this indicator is widely used abroad in the soil quality control system both in the field and in laboratory conditions.

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Changes in electrical conductivity along the soil profile reflect the features of ionization of individual horizons as a result of phase transitions of substances associated with changes in temperature, humidity, redox processes, intensity of mineralization processes, migration of ions and ionized components [4].

Traditionally, electrical conductivity was used to diagnose soil salinity, but recently the use of electrical conductivity values to diagnose other parameters of soil fertility has become widely used in agronomic practice, primarily due to the availability and cheapness of measurements [5]. Quite strong correlation dependences of electrical conductivity with other important agronomic characteristics of the soil were found, in particular, the content of organic substances in the soil, mobile forms of the main nutrients, the presence of Ca, Mg in the soil absorption complex, and the yield of agricultural crops [6; 7].

The dependence of soil electrical conductivity on contamination with heavy metals, hydrocarbons, and pesticides is studied [8]. It was established that electrical conductivity depends on soil moisture, salt concentration, air content, temperature, type of soil-forming rock, etc. In particular, electrical conductivity increases with increasing soil moisture until full moisture capacity is reached, and then remains relatively constant. The presence of clay minerals montmorillonite, illite, and vermiculite in the soil-forming rock contribute to a certain increase in the electrical conductivity of the soil in comparison with sandy soils [9; 10].

The use of fertilizers, especially in significant amounts, can change the amount of soluble mineral salts in the soil, thereby increasing electrical conductivity, which can also have a negative effect on the yield of agricultural cultures [11; 12]. Of particular interest for studying changes in soil electrical conductivity and establishing correlations between it and the main agronomic characteristics of soil fertility and agrocenosis productivity are long-term experiments with the introduction of different rates of fertilizers under different fertilization systems for crops [9].

The purpose of the study is to compare the changes in the electrophysical parameters of typical chernozem under different fertilization systems under conditions of drip irrigation.

The research was carried out by field and laboratory methods within the Forest-Steppe Zone of Ukraine, on the territory of the Educational-Scientific-Production Center "Experimental Field" of the Kharkiv National Agrarian University named after V.V. Dokuchaeva, where strawberries are grown on drip irrigation with fertilizer for the third year in a row.

The following options were chosen for research in the field where garden strawberries are grown (4 rows in each option):

1. option – control (without fertilizers);
2. option – mineral system ($N_{64}P_{64}K_{64}$);
3. the organo-mineral system option ($N_{64}P_{64}K_{64}$+manure 50 t/ha);
4. option – organic system (manure 50 t/ha).

Additional options for conducting research in 2020 were chosen:

5. variant (black steam) – a field of field crop rotation (more than 100 years) without the use of irrigation;
6. option (overlay) – herbaceous vegetation, more than 70 years old.

An experiment for strawberries of the garden variety "Roksana" was laid in the fall of 2017 on an area of 0.3 hectares. Planting was carried out using ridge technology with the use of a mulching film and drip irrigation. The predecessor of strawberries was black steam.

Nitroamophoska $N_{16}P_{16}K_{16}$ and semi-rotted manure were used for fertilization in the experiment. Strawberry planting was carried out in a staggered staggered order in two strips with a distance between plants of 25 cm with rows of 130 cm. Watering was carried out as needed to ensure constant soil moisture within 75%, which was measured by a field hygrometer. The technology of the cultivation system provides for the use of chemical plant protection agents against harmful organisms and non-root feeding during the flowering phase.

Electrophysical indicators were studied in samples of typical deep heavy loam black soil on loess loam from the surface layer of the soil – the ridge (in the experiment with the cultivation of garden strawberries), and then every 10 cm to a depth of 50 cm in the specified variants of the experiment

MATERIALS AND METHODS

Individual soil samples were taken in each research year (2018-2020) in the spring (May) before the start of strawberry flowering. Average mixed samples for analysis were selected from the selected and air-dried soil samples using the quarting method. After that, the average mixed samples were sieved through a Ø1 mm sieve. The soil that did not pass through the sieve was crushed in a mortar. Sand fractions that did not pass through the sieve were added to the sample. Soil samples from each soil layer were placed in storage bags.

Aqueous soil suspension (1:5) was prepared by mixing 10 g of air-dry soil with 50 ml of distilled water in a polypropylene container, intensively stirred for 2 minutes and left for 1 hour to settle the soil-water suspension.

With the help of a conductometer-salt meter (EZODO-8200 M), electrophysical indicators were determined in the upper part of the soil-water suspension (electrical conductivity, general mineralization, salinity). Analyzes were performed in three to five times.

RESULTS AND DISCUSSION

Studies of electrophysical indicators are very rarely used when determining the properties and genesis of soils. At the same time, as noted by a number of authors, a certain simplicity and speed of determination, as well as a wide range of these indicators in connection with changes in the physical factors of the environment, testify in their favor [13; 14; 15].

In our research,was studied the effect of drip irrigation (control option) and application of fertilizers (mineral, organo-mineral, organic) on the electrical conductivity of aqueous soil suspensions.

Electrical conductivity (Soil Conductivity) of typical chernozem. According to the research results obtained in 2020, a pattern of increasing electrical conductivity with depth can be observed in the options with strawberry cultivation, and in the option without irrigation and the fallow option there are some peculiarities regarding the distribution of values (Fig. 1).

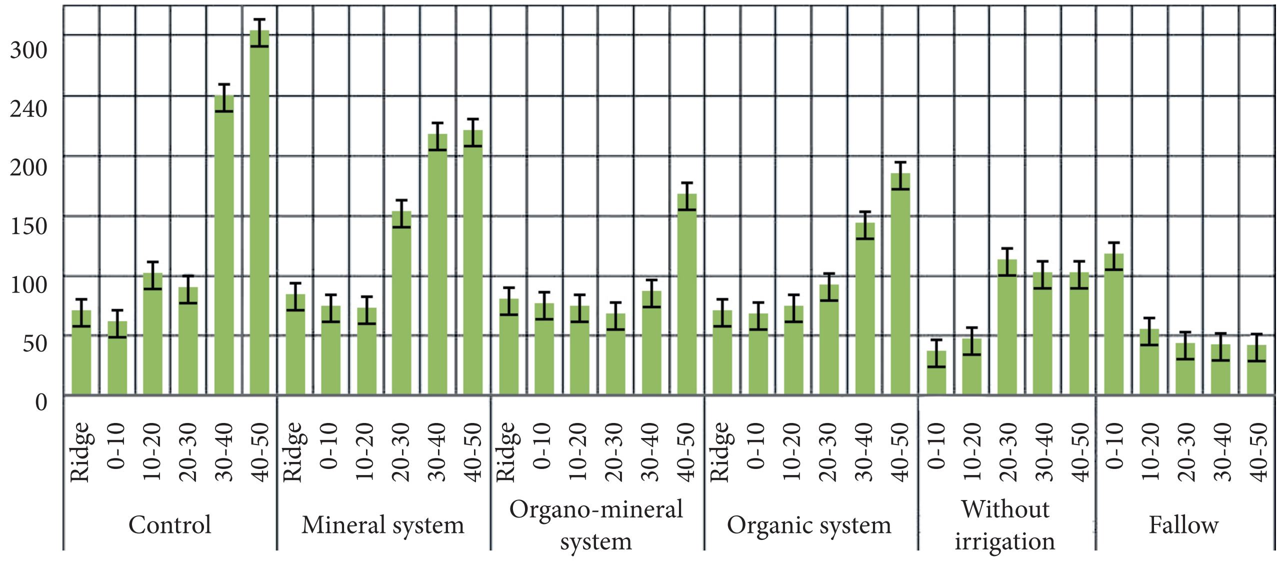

Figure 1. *Electrical conductivity of typical chernozems (2020), µS/cm (NIR$_{05}$=7)*

Thus, on the control version, the electrical conductivity of the ridge part and the 0-20-cm layer is within the smallest significant difference – 60-65 µs/cm ((*HIP*$_{05}$=7). A slight increase starts from a depth of 20-30 cm, and a very significant one - from 30-40 cm up to 249 µs/cm and up to 302 µs/cm in a 40-50 centimeter layer.

The mineral fertilizer system is characterized by a similar trend in the distribution of indicators. Electrical conductivity decreases from the crest to 10-20 centimeters from 83 to 71 µs/cm. In the middle part of the studied depth, the indicators increase by more than 2 times, and the 30-50 centimeter layer has a value of 216-219 µs/cm, which is 2.5-2.6 times more than the upper layers.

On the variant with the organo-mineral system, there is a slight fluctuation of the electrical conductivity of the water-soil suspension up to a depth of 30-40 cm, and the increase in the indicator occurs only in the lower investigated depth of 40-50 cm – 166 µs/cm, which is 2 times more than the lower layers.

The use of an organic fertilization system leads to a gradual increase in values from the upper part to 20-30 centimeters. At a depth of 30-40 cm, there is a 2-fold increase in the indicator compared to the ridge part to 140µs/cm, and its increase by 42 µs/cm in the 40-50 cm part.

The option without irrigation has the lowest values in the 0-10 and 10-20 cm layers. Then the indicator increases sharply to 111 µs/cm and slightly decreases by 10 µs/cm in the 30-40 and 40-50 centimeter soil layer.

The highest values in the 0-10 cm layer were recorded on the fallow variant at 116 µs/cm. In a layer of 10-20 cm, the electrical conductivity decreases by more than 2 times, and further to a depth of 40-50 cm, it decreases by more than 2.5 times to 39-40 µs/cm.

Taking into account all the studied options, we can say that the highest values of electrical conductivity are in the lower part from 30 to 40 centimeters in the options of control and mineral fertilizer system. Mediocre indicators, also in the lower investigated part, on the variant of the organo-mineral system and the organic fertilizer system, and another 20-30 centimeter soil thickness of the mineral system.

The lowest electrical conductivity of water-soil suspensions is observed in most options in the ridge part and up to 20-30 centimeters, and in the options without irrigation and fallow, all values can be characterized as the lowest among the research options. Such low values of electrical conductivity in the spring period are formed due to the strengthening of processes of assimilation of nutrients by garden strawberry plants from the soil, as a result of intensive growth.

The specific electrical conductivity of the soil during drip irrigation in the garden strawberry growing options was 60-302 µs/cm. The area has a partial leaching of salts (nutrients) into the lower layers of the soil, which can be caused by the use of drip irrigation and the technology of growing plants using a film, which prevents the evaporation of water together with easily soluble salts into the upper layers of the soil. Therefore, from a depth of 30 cm, there is an increase in the specific electrical conductivity of the soil to 140-302 μs/cm.

When growing strawberry crops without the use of fertilizers in our experiment, the electrical conductivity of the soil was at the level of 60-302 μs/cm. The use of only manure for fertilizing crops practically did not change the electrical conductivity of the upper layers of the soil. The use of organo-mineral and mineral fertilization systems leads to some increase in the indicator. At the same time, the greatest increase in electrical conductivity of the soil was observed in the mineral system [9].

Similar trends in the increase in electrical conductivity when mineral fertilizers are applied are expected and confirmed by the research of other scientists. During the three-year period of the experiment, the electrical conductivity of the soil with the mineral fertilizer system is the highest among the variants of the experiment. However, at the same time, the soil, according to the classification of the Food and Agricultural Organization of the United Nations, remains within the limits of electrical conductivity, which characterize it as not saline. In other words, the electrical conductivity indicators do not exceed the level that can be harmful to plants [9; 16].

Electrical conductivity of irrigation water. For drip irrigation, when watering is carried out quite often, it can be assumed that the soil solution and irrigation water are identical. For cultures, theoretical maximum values of electrical conductivity were established, below which plants cannot grow. To determine the theoretical yield reduction from the use of specific irrigation water, the electrical conductivity of the water is determined, which is much easier than determining the electrical conductivity in the soil. Next, the electrical conductivity of water is compared with the limit values of the electrical conductivity of the soil. If the electrical conductivity of the water is lower, then they conclude that a decrease in yield due to salinity is not expected. Otherwise, they say about a decrease in productivity.

So, the water used for irrigation has the following measured characteristics: electrical conductivity – 1142 μs/cm; total mineralization – 757 ppm; salinity – 570 ppm; pH of water is 6.88.

According to the literature, the threshold value of electrical conductivity for irrigation water of loamy soils is 900 μs/cm. Accordingly, in our case, the exaggeration of the indicator is 242 μs/cm, which can negatively affect the productivity of garden strawberry plants.

In the general case, the following levels are set for the assessment of irrigation water by electrical conductivity, presented in Table. 1.

Table 1. Classification of irrigation water by electrical conductivity

Electrical conductivity of water, μs/cm	Classification of irrigation water according to mineralization (level of soluble salts content)
<650	low
650-1300	average
1300-2900	high
2900-5200	very tall
>5200	extremely high

After determining the actual salinity of irrigation water, a conclusion is made about the feasibility of growing this crop or another crop is chosen that can grow in these conditions without reducing productivity.

Therefore, according to the level of the content of soluble salts, irrigation water can be classified as moderately saline. *Total mineralization (Total Dissolved Solids) of typical chernozem.* Characterizing the general mineralization separately for each variant of research, the largest values can be traced in the lower layers, and the smallest - in the upper ones (Fig. 2). Thus, the total mineralization on the control version is equal to 40-46 ppm, the version with mineral fertilizer 47-56 ppm, organic-mineral – 44-57 ppm, and only organic - 43-60 ppm and increases to values of 110-200 ppm.

The option without irrigation has a value of 73 ppm in a layer of 20-30 cm, which corresponds to the largest and 20 ppm in a layer of 10-20 cm – the smallest value of the option. The fallow variant of use is characterized by an increase in total mineralization in the upper 0-10 centimeter layer of the soil – 77 ppm and its subsequent decrease to 35-26 ppm in the depths.

According to the indicator of total mineralization, the highest values among all research options were found on the control and mineral fertilizer system from a depth of 30 to 50 cm – 165-199 ppm and 142-144 ppm, respectively. We have average values in soil samples from a depth of 30-40 and 40-50 cm of the organic system – 93 and 120 ppm, of the organo-mineral system, only at a depth of 40-50 cm – 110 ppm and 20-30 centimeter thickness of the variant of the mineral system – 101 ppm. All other values of the indicator of total mineralization can be classified as low – from 40 to 60 ppm. Also, the options without irrigation and the fallow option for all studied depths from 0 to 50 cm are subject to the lowest values of total mineralization.

Salinity (Salinity) of typical chernozem. The salinity of the soil of the control variant begins to increase from 31-36 ppm from the upper part to 10-20 cm and 45 ppm at 20-30 cm (Fig. 3). In the layers of 30-40 and 40-50 cm, the highest values were found – 125 and 151 ppm.

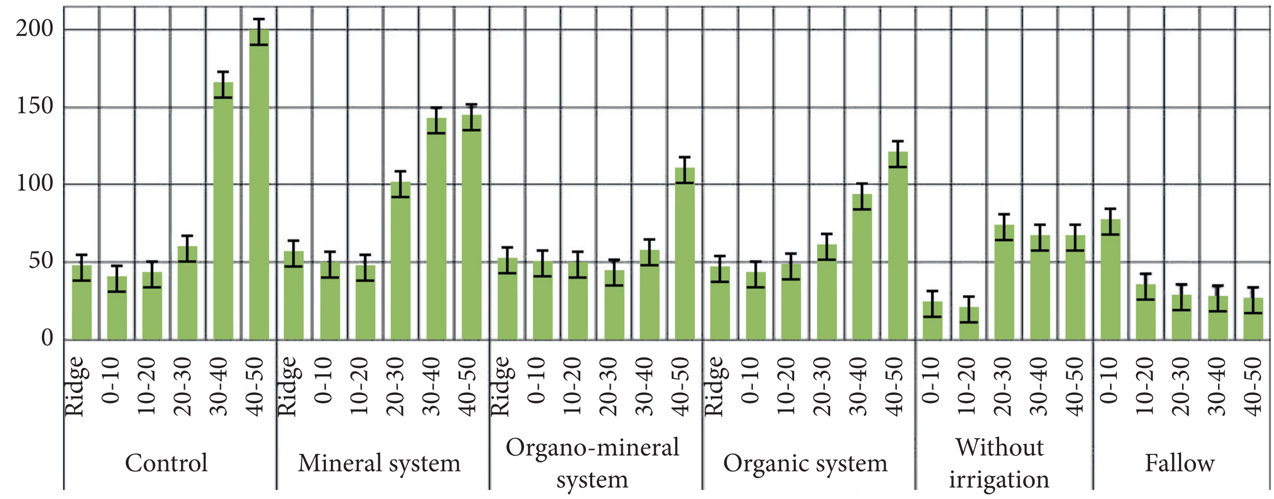

Figure 2. *General mineralization of typical chernozems (2020), ppm (HIP$_{05}$=5)*

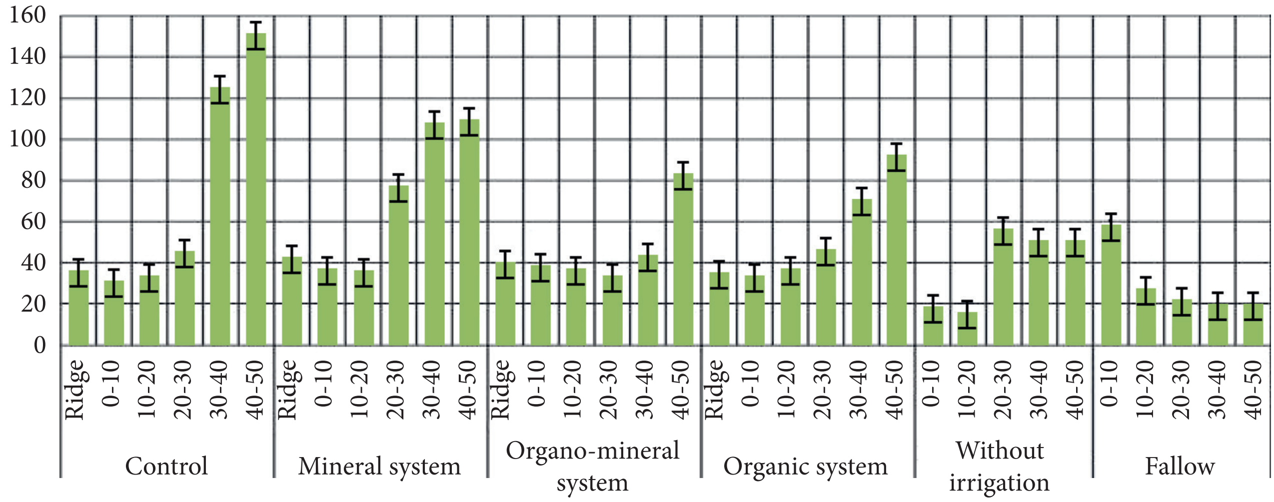

Figure 3. *Salinity of typical chernozems (2020), ppm (NIR$_{05}$=4)*

On the version of the mineral system, first there is a slight decrease in values from 42 to 36 ppm, and then an increase more than twice and a significant increase (NIP$_{05}$=4) in the 30-50 cm layer to 108-109 ppm.

The organo-mineral fertilizer system is also characterized by almost similar salinity indicators with a difference in the upper part of 2-3 ppm, but the highest value of 83 ppm in a layer of 40-50 cm (less than 26 ppm).

The organic fertilizer system has salinity in the upper part at the level of indicators of the control variant, and in the lower part - the variant of the organo-mineral system.

The value of 56 ppm corresponds to the highest value in the version without irrigation in the layer of 20-30 cm. Smaller values of 15-19 ppm were recorded in the upper layers, and higher values in the lower ones – 50-51 ppm. In the 0-10 cm layer of the fallow variant, in contrast, salinity of 58 ppm is highest in the 0-10 cm layer, with a sharp 2-fold decrease in the next 10 cm layer and fluctuations within the smallest significant difference in the 10 to 50 cm layers.

We have the highest values of the salinity index in the control options and the mineral fertilizer system in the two lower studied layers. The lowest values correspond to the upper ridge parts and 0-30, 0-40 centimeter layers. Similarly, the lowest values are observed in all 10-centimeter layers of variants without irrigation and fallow.

Correlation of electrical conductivity data and soil pH. We conducted a correlational analysis of data on the dependence of water pH and salt pH on electrical conductivity, general mineralization, and salinity of soil-water suspensions (Table 2).

Table 2. Correlation matrix of data of electrophysical parameters and pH of typical chernozem

Cond	–	1,00	1,00	0,62	0,67
TDS	1,00	–	1,00	0,62	0,67
Salt	1,00	1,00	–	0,62	0,67
pH water	0,62	0,62	0,62	–	0,93
pH salt	0,67	0,67	0,67	0,93	–
	Cond	**TDS**	**Salt**	**pH water**	**pH salt**

On the control version, the correlation of electrical conductivity and aqueous pH is 0.88, and with saline pH is 0.91, which corresponds to a very strong direct relationship. The following option with the use of a mineral fertilizer system has a similar dependence – 0.96 and 0.98, respectively.

An even greater correlation between these data can be observed on the option without drip irrigation – 0.97 and 0.98.

The variant with organo-mineral fertilizer is characterized by an average inverse correlation of electrophysical parameters and aqueous pH, but a strong direct correlation with saline pH – 0.76.

On the version of the organic system, feedbacks were recorded with water pH – -0.87 and salt pH – -0.69. The variant of fallow use has a practically similar, but even greater inverse correlation dependence, where the relationship between electrical conductivity and water pH is -0.94, and salt pH is -0.79.

However, first of all, based on the obtained data arrays, we can state a very strong direct correlation between the water and salt pH data, which is 0.93. Secondly, a strong direct relationship between pH data (aqueous and saline) and indicators of electrical conductivity, salinity and general mineralization was revealed. The correlation between electrophysical indicators and aqueous pH is 0.62, and saline pH is 0.67 (Table 2).

Dynamics of changes in electrophysical parameters of typical chernozem. According to the data obtained during the 2018-2020 research, we can trace the dynamics of electrophysical indicators on the variants with the cultivation of garden strawberries (Fig. 4).

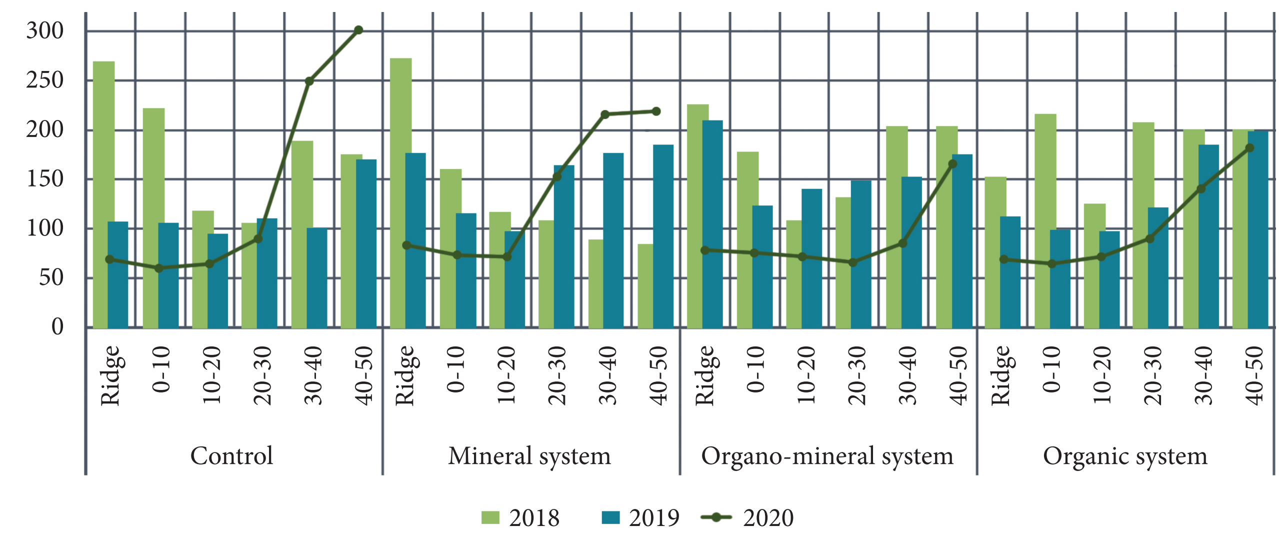

Figure 4. *Dynamics of changes in electrical conductivity of typical chernozem under different fertilization options (2018-2020), μs/cm (NIR$_{05}$ 2018=5; 2019=10; 2020=7)*

Thus, on the control variant, the highest values were found in the 30-40 and 40-50-centimeter soil layer in 2020 of the study (249 and 302 μs/cm) and the ridge part of 2018 (268 μs/cm). We have average values in 2018 and 2019 in the lower studied part of the soil, and the lowest in the middle of 2018 and the upper part of the control version in 2019, 2020 (93-106, 60-89 μs/cm).

The dynamics of the highest values of the variant with the use of mineral fertilizers shows the highest values in the ridge part of 2018 (272 μs/cm) and, conversely, the lower one – in 2020 (219 μs/cm).

Average electrical conductivity in most of the analyzed samples in 2019 (163-183 μs/cm).

The lowest values in the soil layer from 10 to 50 cm in 2018 (83-115 μs/cm) and the upper part up to 20 cm in 2020 (71-83 μs/cm).

The highest electrical conductivity of soil-water suspensions in 2018 on the option of organic-mineral fertilizer in the upper and lower parts of the studied depth. In most cases, the electrical conductivity in 2019 is average (122-151 μs/cm), and in 2020 it is low (66-86 μs/cm).

The organic fertilizer option is characterized by the highest values of 2018 research (high – 197-215 μs/cm and average electrical conductivity – 124-151 μs/cm). Low values of the indicator were recorded up to 20-30 cm in 2019 and 2020 (respectively 97-110 and 65-90 μs/cm), and the highest, again, in the thickness of 30-40 and 40-50 cm (182-198 μs /cm).

Therefore, in most cases, there is a decrease in the electrical conductivity of soil-water suspensions in 2020 of the research compared to 2019 and 2018, which may be caused by a decrease in the content of available nutrients and organic matter, since fertilizers were applied only in the year of the experiment (2017) or by weakening the biological activity of the soil.

The biggest changes occurred in the control variant in the comb part, where the values decreased from 268 μs/cm in 2018 to 69 μs/cm in 2020, the variant of the mineral system (decrease by 189 μs/cm) and organo-mineral (decrease by 146 μs /cm).

On the contrary, an increase in electrical conductivity occurred in 2020 compared to previous years in the lower studied stratum of the control options and the mineral fertilizer system. The 30-40 and 40-50 centimeter thickness of the organic fertilizer variant is characterized by practically constant indicators for three years. According to indicators of total mineralization and salinity, a similar trend is observed regarding the dynamics of changes, but somewhat with other digital indicators.

CONCLUSIONS

Electrophysical indicators change depending on the depth of sampling, which is related to the assimilation of nutrients from the soil by plants and fertilization systems and correlates to a large extent with the acid-base characteristics of the soil.

The study of the electrical conductivity of 2020 typical chernozem when growing strawberry crops without the use of fertilizers was at the level of 60-302 μs/cm. The use of only manure for fertilizing crops practically did not change the electrical conductivity of the upper layers of the soil. The use of organo-mineral and mineral fertilization systems leads to some increase in the indicator. At the same time, the highest electrical conductivity of the soil was observed in the mineral system, where mineral fertilizers that acidify the soil are an additional factor of influence, which, accordingly, leads to a decrease in electrical conductivity.

With the help of the electrical conductivity indicator, it is possible to quickly determine the suitability of water for irrigation of the planned crop with a known granulometric composition of the soil. Therefore, the use of water for drip irrigation with an average content of soluble salts leads to their accumulation in the soil.

Based on the dynamics of the obtained values, we can state that in most cases there is a decrease in the electrical conductivity of soil-water suspensions in 2020 of the research compared to 2019 and 2018, which may be caused by a decrease in the content of available nutrients, organic matter, or a weakening of the biological activity of the soil .

The obtained data confirm the effectiveness and efficiency of the use of electrophysical parameters of the soil during the application of fertilizers and the use of drip irrigation.

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Використання електрофізичних показників під час вирощування суниці на краплинному зрошенні

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Анотація. Електрофізичні методи дослідження є широко використовуваними у країнах з розвиненим аграрним виробництвом з метою проведення грунтових моніторингу та обстежень. Одним з таких методів досліджень є визначення електропровідності ґрунту. Оскільки за допомоги цього показника релевантно уточнювати межі грунтових відмін, що дає змогу застосовувати його у точному землеробстві. Таким чином, метою статті є порівняння змін електрофізичних показників чорнозему типового за різних систем удобрення в умовах краплинного зрошення. Задля здійснення аналізу було відібрано індивідуальні зразки ґрунту кожного року досліджень в період 2018-2020 рр. навесні (травень) до початку цвітіння суниці. Із відібраних та висушених до повітряно-сухого стану ґрунтових зразків методом квартування було відібрано середні змішані зразки для проведення аналізу. Зроблено висновок, що електрофізичні показники зазнають змін відповідно до глибини відбору зразків, що пов'язано із засвоєнням корисних речовин із ґрунту рослинами та механізмів удобрення і корелюють у значній мірі із кислотно-лужними показниками ґрунту. Проведено трирічні дослідження (2018-2020) впливу різних систем удобрення в умовах крапельного зрошення на електрофізичні показники чорнозему типового під час вирощування суниці садової. Встановлено, що найбільші зміни електрофізичних показників (електропровідність, загальна мінералізація, солоність) чорнозему типового відбуваються від гребеневої частини до глибини 20-30 см. Виявлена відмінність в отриманих значеннях електрофізичних показників між варіантами різного удобрення чорнозему типового (контрольний, мінеральна система, органо-мінеральна система, органічна система), а також протягом років досліджень

Ключові слова: слова: чорнозем типовий, електрофізичні показники, крапельне зрошення, удобрення