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INFLUENCE OF DRIP IRRIGATION ON THE CHEMICAL PARAMETERS OF TYPICAL CHERNOZEM

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Abstract

Research studies have proven that results obtained with LAQUAtwin pocket meters are strongly correlated with those of traditional laboratory analyses. The LAQUAtwin pocket meters allow direct measurement of micro-volume sample (as low as 0.1 ml) and deliver results in just a few seconds. These advantages enable to make fertilization and irrigation decisions quickly. Regular monitoring of nutrient levels such as sodium (Na^+), potassium (K^+) and calcium (Ca^{2+}) in plant petioles, soil solution, irrigation water produces not only good yield and fruit quality, but also reduces fertilizer cost and mitigates environmental hazards. The LAQUAtwin pocket meters are the perfect tools for testing as they directly measure samples and provide results in just few seconds allowing growers to identify and correct any nutrient deficiency or excess immediately.

Key words: *chernozem, irrigation, chemical parameters.*

INTRODUCTION

Agriculture analysis is a very important aspect to crop growing. To increase quality and yields, it is crucial to understand the current nutrient levels of the soil to be able to ascertain which areas require improvement (Greig, 2009).

Soil and plant tissue testing is a valuable tool for determining the fertilizer needs and maximizing the fertilizer efficiency.

Soil test is especially useful early in the growing season when plants are too small to collect tissue samples (Hoeft, 2001). Following soil indicators are used more often: soil pH, conductivity, the content of calcium, sodium, potassium, nitrate in soil solution.

Plant tissue test for nitrogen (N) and potassium (K) levels during the growing season provides information for diagnosing problems.

It is preferred than soil test as the results of which can change quickly by rain or irrigation (Campbell, 2000).

Plant sap testing offers advantages over the conventional dry tissue testing being carried out in laboratories.

Aside from the lower cost it requires, plant sap testing can be easily done in the field and the results can be obtained quickly which is important in making fertilization decisions (Horneck, 1998).

Plant sap analysis has been used by growers to manage crop nutrient content and fertilization strategies.

A plant sap test gives a view of the nutrients available for the plant, at that time, for growth or development. It directly shows if a crop suffers from a nutrient deficiency or an excess.

Soil solution analysis is also important for growers. It gives a view of the nutrient and salinity levels in the soil and nutrient leaching past the root zone.

Soil solution is the water held in the soil, which contains a mixture of nutrients taken up by roots (Bottoms, 2013). All plants need calcium rich soil to grow. The calcium is used by the plant in developing the plant cell walls and membranes. Furthermore, it is a non-leaching mineral (it will stay in the soil) and will improve water penetrability and reduce soil salinity. It is thus helpful to determine the amount of calcium contained in soil (Vardar, 2015). The use of accurate calcium ion testing in controlling the calcium content of soil ensures that the plants which are grown in the soil are given the necessary minerals and can easily absorb water.

Sodium is a mineral constantly present in soil, but an excess of it can cause the yield to dwindle. Thus, it is beneficial to measure the salinity of soil on which crops are grown.

Strawberry production requires a root environment with good availability of essential nutrients to achieve optimum plant growth, fruit quality, and yield.

Soil pH influences on the availability of nutrients such as nitrate (NO_3^-), potassium (K^+) and calcium (Ca^{2+}) ions, which have specific roles in strawberry fruit quality. For example, NO_3^- determines the size, K^+ influences the taste, and Ca^{2+} affects the firmness.

The nutrients should be present in a right balance to avoid competition or improper plant uptake. Soil pH is a measure of the acidity or alkalinity in soils. In the pH scale, pH 7.0 is neutral. Below 7.0 is acidic and above 7.0 is basic or alkaline. Soil pH affects nutrients available for plant growth.

In highly acidic soil, aluminum and manganese can become more available and more toxic to plant while calcium, phosphorus, and magnesium are less available to the plant. In highly alkaline soil, phosphorus and most micronutrients become less available (Casteel, 2004).

The desirable soil pH range for optimum plant growth varies among crops. Generally, soil pH 6.0-7.5 is acceptable for most plants as most nutrients become available in this pH range.

Soil pH can be determined by mixing soil sample with water (in a ratio 1:5) and then measuring the resulting aqueous solution.

By the way, conductivity should be monitored due to the strawberry plants do not tolerate high conductivity value (Hicks, 2015).

Soil solution analysis can help growers make decisions about their irrigation and nutrient management program (Casteel, 2004). It should be used to enhance nutrient management and not as a measure of overall soil nutrient status. Nitrate and salinity levels are the key focus of soil solution monitoring. As nitrate is a highly mobile nutrient, soil solution can help identify incorrect nitrogen application, which could result in nitrate accumulation within the root zone and nitrate leaching below the root zone (Bottoms, 2014). Potassium and calcium are bound to soil and their levels in soil solution do not provide a reliable indication of their supply and availability to the crop. However, potassium, calcium, and sodium levels in soil, irrigation water, and drain water should be checked regularly.

Salinity levels measured in soil solution allow growers to perform corrective action (e.g., increase irrigation to maintain salinity levels) before symptoms appear on leaves, yields or crop quality.

Overwatering leaches fertilizer out of the root zone and results in environmental hazard (e.g., groundwater contamination).

Soil solution analysis can be tested throughout the growing season (Baliuk, 2016).

Fertigation management requires rapid and accurate methods to determine nutrient concentrations in soil solution and plant sap (Ancay, 2014). Folegatti et al. (2005) found that the concentrations of Ca^{2+}, K^+, and Na^+ in soil solution determined by LAQUAtwin ion pocket meters showed good correlations with those obtained in soil solution determined by standard methods in laboratory, and concluded that LAQUAtwin ion pocket meters are useful low-cost tools in fertigation management.

The aim of our study was to investigate changes in the chemical parameters (calcium, sodium and potassium content) of Calcic Voronic Chernozem under the influence of drip irrigation by using LAQUAtwin devices.

MATERIALS AND METHODS

Our field site was the Research Field of the Study, Research and Production Centre (SRPC) in Kharkiv District that was laid out in 1946 under Professor OM Grinchenko. The soil is thick Calcic Voronic Chernozem (typical heavy loamy chernozem on the loess-like loam) that has been tilled for more than a century. Since 1946, some has been set aside as natural grassland, most is still cultivated under arable rotations.

The experiment for strawberry garden variety ‘Roxana’ was laid in the fall of 2017 on an area of 0.3 hectares. Planting was carried out by comb technology using mulching film and drip irrigation. The precursor for strawberries was black couples (Figure 1).

In the experiment, nitroammophoska $N_{16}P_{16}K_{16}$ and half-roasted manure were used for fertilization. Strawberries were planted in a checkerboard pattern in two strips with a distance between plants of 25 cm with rows of 130 cm. Irrigation was carried out as needed to ensure a constant soil moisture within 75%, which was measured with a field moisture meter. The technology of the cultivation system provides for the use of chemical plant protection products against pests and non-root fertilization in the flowering phase.

Figure 1. General view of a strawberry field

For research in the field where grown strawberry were selected following variants (4 rows in each variant):

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

Additional variants in 2020 year for research were selected:

- Variant 5 (black couples) - field crop rotation (more than 100 years) without irrigation;
- Variant 6 (fallow) - herbaceous vegetation over 70 years old.

Chemical parameters were studied in Calcic Voronic Chernozem samples, which were taken from the surface layer of the soil (ridge - in the experiment with growing garden strawberries), and then every 10 cm to a depth of 50 cm in these variants of the experiment.

Method for determining chemical parameters. Take a soil simple to measure, at the roots depth in order to get a precise idea of the nutrient levels at the root's systems depth. Take various samples to have a homogeneous representation of the culture. Pass the soil simple through a sieve to remove stones and organic matter. Weigh 10 grams of soil samples. Prepare a 1:1 dilution with distilled water (10 ml). Mix the soil and water for 2 minimum and let the paste settled for 5 minutes. Place the paste obtained on the LAQUAtwin sensor after calibrating the meter. For the ions, multiply the Reading per the dilution factor (x2) to calculate the real concentration of nutrient in soil.

RESULTS AND DISCUSSIONS

The amount of water-soluble salts in irrigated soils depends on the quality of irrigation water and the use of fertilizers (organic, mineral, organo-mineral).

In the control variant with the use of irrigation without fertilizer in the first year of the experiment (2018) the amount of water-soluble sodium decreased sharply from 360 ppm in the ridge to 40 ppm in the layer of 40-50 cm. Compared to the following year (2019), the amount of sodium decreased more than 2 times in the ridge and more than 1.5 times in the layer 0-10 cm.

The following studied layers have almost no significant fluctuations compared to the previous year of sampling. The third year of research shows a slight decrease in water-soluble sodium by 34 ppm in the ridge and a sharp increase in the lower investigated soil thickness to 200 ppm (Table 1).

The amount of water-soluble calcium on the contrary increases from the upper part of the profile to the lower during three years of research. However, in the third year of research, its number begins to decrease sharply in the ridge and subsequent layers. This leads to a sharp decrease in the ratio of Ca:Na. Fluctuations in calcium content occur in the range from 88 to 110 ppm, which is 1.5-2.5 times less than in previous years. In addition, the water-soluble calcium content of the 30-40 and 40-50 cm layers is increased to 340 and 420 ppm.

Other variants of the experiment have a similar tendency in the distribution of water-soluble sodium and calcium content. Thus, under the mineral system of fertilizer, the sodium content gradually decreased from 300 ppm to 28 ppm in the 40-50 cm layer, and from 320 ppm to 158 ppm, then increased to 200-280 ppm of water-soluble calcium occurs in the first year of study. The following year, the amount of water-soluble sodium ranges from 114-142 ppm from the top to 30 cm and from 78-102 ppm from 30 to 50 cm.

Table 1. Dynamics of water-soluble sodium and calcium content (ppm)

Variant	Depth, cm	Na, ppm			Ca, ppm			Ca:Na		
		2018	2019	2020	2018	2019	2020	2018	2019	2020
Control	ridge	360	172	138	220	166	106	0.6	1.0	0.8
	0-10	280	150	152	240	198	88	0.9	1.3	0.6
	10-20	120	126	186	186	200	90	1.6	1.6	0.5
	20-30	134	132	192	168	280	110	1.3	2.1	0.6
	30-40	80	98	200	320	280	340	4.0	2.9	1.7
	40-50	40	88	174	340	360	420	8.5	4.1	2.4
Mineral system	ridge	300	116	144	320	360	126	1.1	3.1	0.9
	0-10	200	142	154	220	200	120	1.1	1.4	0.8
	10-20	158	142	176	158	200	90	1.0	1.4	0.5
	20-30	108	114	220	200	360	240	1.9	3.2	1.1
	30-40	96	102	176	220	340	260	2.3	3.3	1.5
	40-50	28	78	154	280	360	280	10.0	4.6	1.8
Organo-mineral system	ridge	164	200	148	380	360	142	2.3	1.8	1.0
	0-10	192	178	164	240	170	118	1.3	1.0	0.7
	10-20	92	136	178	260	280	94	2.8	2.1	0.5
	20-30	94	102	170	300	340	84	3.2	3.3	0.5
	30-40	130	88	158	340	380	104	2.6	4.3	0.7
	40-50	116	38	180	320	480	260	2.8	12.6	1.4
Organic system	ridge	142	166	124	280	154	118	2.0	0.9	1.0
	0-10	170	134	136	380	186	94	2.2	1.4	0.7
	10-20	52	154	168	320	200	92	6.2	1.3	0.5
	20-30	80	164	184	400	300	106	5.0	1.8	0.6
	30-40	68	144	220	400	320	170	5.9	2.2	0.8
	40-50	18	122	200	420	340	220	23.3	2.8	1.1

At the same time, the decrease in calcium content is observed at depths of 0-10 and 10-20 cm to 200 ppm, and other layers had slight fluctuations from 340 to 360 ppm. Some increase in sodium to 100 ppm was observed in the third year of the experiment in all soil layers. In addition, the calcium content decreases sharply in the third year of the experiment to a depth of 20 cm and, as a consequence, the ratio of calcium to sodium is in the range of 0.5-0.9.

Slightly lower values of water-soluble sodium were recorded in the variant with organo-mineral fertilizer system up to 164 ppm in the ridge and 192 ppm in the 0-10 cm layer. Unlike previous variants, the increase in sodium content occurs in the second year of research in the ridge to 200 ppm, and then its amount gradually decreases. Practically the highest indicators of water-soluble sodium from 148 to 180 ppm were obtained for the third year of the experiment. The amount of water-soluble calcium in the first year of research was the highest in the ridge - 380 ppm, and then decreased to 240 ppm, and increased to 320-340 ppm. Mediocre values were obtained for the second year, and the lowest (from 84 to 142 ppm) - for the third, where the ratio of Ca:Na was the highest in the upper part of the soil (1.0) and gradually decreased to 0.5 (Table 1).

The organic fertilizer system is characterized by the redistribution of the resultant values according to the content from the ridge (142 ppm) to the lower thickness of 40-50 cm (total 18 ppm). In the second year of research, the amount of water-soluble sodium is slightly increasing, both in the upper part of the profile and especially in the lower part. A sharp increase in sodium content compared to the first year occurs from a depth of 10-20 cm from 168 ppm to 200-220 ppm at a depth of 30-50 cm. Also, this variant revealed the highest content of water-soluble calcium in almost the entire study thickness, and especially at a depth of 40-50 cm, where the figure reaches 420 ppm. The Ca:Na ratio in the studied soil reached the level of the variant without irrigation and fallow - 23. But, next year the amount of calcium decreases sharply by 1.5-2.0 times to a depth of 10-20 cm. Even more significant changes compared to the first year of research can be traced to the third year. Thus, the calcium content decreases by another 2.0-2.5 and 3.5-4.0 times.

Thus, we have practically the highest content of water-soluble sodium in the variant of control and mineral system in the ridge part of the soil in 2018. Indicators in the ridge part of the soil in 2019 are slightly decreasing, but are the largest in the control variant, organo-mineral and organic system. In 2020, the highest values were recorded in the lower part of the profiles of control variant and the organic system. The lowest values are observed during the first two years of all variants of the experiment at depths of 30-40 and 40-50 cm, and for the third year - in the upper layers (ridge).

In contrast, the highest content of water-soluble calcium, within three years, is in 30-40 and 40-50 cm thick of all research variants. The lowest calcium content for three years on the control variant from the ridge to 10-20 cm.

None of the analyzed variants revealed water-soluble potassium content, except for single samples. Thus, the insignificant potassium content was 8 and 10 ppm on the control variant and organo-mineral fertilizer system for the first year of research. A slightly higher figure was obtained in the variant of fallow, where the water-soluble potassium content was 24 ppm.

Based on the dynamics of the obtained values during the three years of research on the content of water-soluble sodium and calcium, we observe that the sodium content gradually increases in all variants of the experiment, and the amount of calcium decreases. As a result, the ratio of Ca:Na decreases. Therefore, the use of irrigation for three years promotes a marked transformation of the content of water-soluble salts.

In addition to these data, in the variant without the use of irrigation, the amount of water-soluble sodium varies slightly from 6 to 12 ppm at all depths studied. The content of water-soluble calcium reaches the level of 200-380 ppm. As a result, the ratio of calcium to sodium is 22-60. In the fallow variant, the sodium content also fluctuates slightly in the range of 8-12 ppm, and the amount of calcium in the upper thickness of 0-10 cm reaches 300 ppm. The ratio of calcium to sodium (Ca:Na) is about 25 (Table 2).

So, by comparing the variants to drip irrigation and without drip irrigation, we can state that drip irrigation during strawberry growing contributes to a significant increase in water-soluble sodium and a decrease in water-soluble calcium in Calcic Voronic Chernozem of all studies. Irrigation of mineral water is the cause, that are confirmed further analysis of the electrical conductivity (soluble salt content) of the irrigation water.

Table 2. Water-soluble sodium and calcium content in 2020 (ppm)

Variant	Depth, cm	Na, ppm	Ca, ppm	Ca:Na
Without irrigation	0-10	8	200	25.0
	10-20	10	220	22.0
	20-30	12	380	31.7
	30-40	10	340	34.0
	40-50	6	360	60.0
Fallow	0-10	12	300	25.0
	10-20	10	240	24.0
	20-30	10	260	26.0
	30-40	10	240	24.0
	40-50	8	240	30.0

For drip irrigation, when watering is carried out often enough, we can assume that the soil solution and irrigation water are identical. Theoretical maximum values of electrical conductivity at which plants cannot grow have been established for crops. To determine the theoretical reduction in yield from the use of a particular irrigation water determine the electrical conductivity of water, which is much easier to do than to determine the electrical conductivity in the soil. Next, compare the electrical conductivity of water with the limit values. If the electrical conductivity of water is less, it is concluded that the reduction in yield due to salinization is not expected. Otherwise, they talk about lower yields.

Thus, the water used for irrigation has the following characteristics: electrical conductivity - 1142 µs/cm; total mineralization - 757 ppm; salinity - 570 ppm; the aqueous pH 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 is 242 µs/cm, which can negatively affect the yield of strawberry plants.

In general, the five levels presented in the table 3 are set for the assessment of irrigation water by electrical conductivity.

After determining the actual salinity of irrigation water make a conclusion about the feasibility of growing this crop or choose another crop that can grow in these conditions without reducing yields.

Therefore, the level of soluble salts of irrigated water can be classified as medium saline.

Changes in pH are one of the main indicators of salinity. The water pH of the control variant increases with depth from the ridge to 50 cm. Thus, the upper part has a value of 7.35 and 0-30 cm thickness is characterized by fluctuations in pH within the smallest significant difference. From a depth of 30-40 cm, the pH of the water rises by 1.50 units compared to the upper soil to 8.81 units (Figure 2).

Table 3. Classification of irrigation water by electrical conductivity

Electrical conductivity of water, µs/cm	Classification of irrigation water by mineralization (the level of soluble salts)
<650	low
650-1300	medium
1300-2900	high
2900-5200	very high
>5200	extremely high

A variant of the mineral fertilizer system recorded a gradual increase in pH from 7.15 to 7.81 to a depth of 20-30 cm inclusive. Then the figure increases and is at the level of 8.96.

Within the smallest significant difference, up to a depth of 20 cm, are the water pH on the variant of simultaneous application of organic and mineral fertilizers. From a depth of 20-30 cm there is a decrease in the water pH first to 7.40 units, and then to 7.21 at a depth of 30-40 cm. Compared with the upper studied thickness (ridge and 0-20 cm), the water pH decreases by 4-5% in the lower part (20-50 cm), which is not typical for the previous two variants of the experiment.

In the variant of the organic fertilizer system, the highest pH value is at a depth of 10-20 cm - 7.48, which is larger than the ridge, 0-10 cm and a thickness of 20-40 cm. The soil layer of 40-50 cm is characterized by a decrease in water pH to 6.87.

Minor fluctuations in the 0-20 cm thickness were detected in the variant without the use of drip irrigation - 6.63-6.48 units. From a depth of 20-30 cm, the pH level rises to 8.41, and then to 8.76 (30-40 cm), which is 25-30% higher compared to the upper layers.

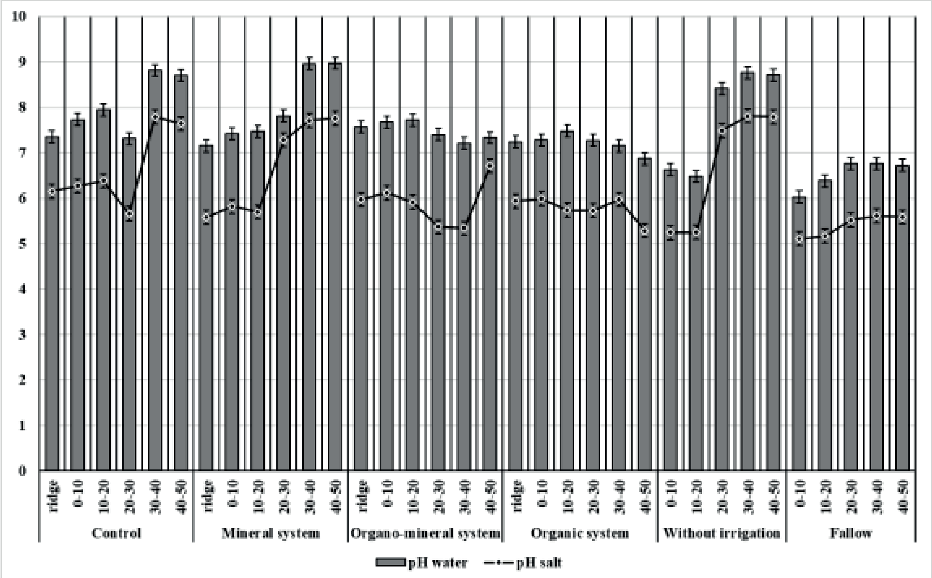

Figure 2. pH water and pH salt of the research variants

The fallow variant of use has a natural increase in water pH from 0-10 cm to 40-50 cm. The values gradually increase from 6.03 to 6.72.

Therefore, the highest values of water pH were recorded in the lower parts of the 30 to 50 cm variant of the control, mineral system, as well as from 20 to 50 cm variant without irrigation.

The lowest pH at all depths in the variant of fallow use, the upper part of the variant without irrigation and 40-50 cm thickness of the variant with organic fertilizer system.

All other indicators can be attributed to the average values ranging from 7.15 to 7.94 (Figure 2).

The pH of the salt of all studies ranges from 5.11 to 7.81 units, corresponds to the reaction of the soil solution from the mild acidic to the medium alkaline.

Thus, the control variant has an increase in the pH salt from 6.15 at the depth of the ridge to 6.38 by layer of 10-20 cm.

The thickness of 20-30 cm is characterized by a decrease in pH to 5.66, and 30-50 cm - a sharp increase to 7.64-7.79, which is 1.5-2.0 units higher than the previous values.

The variant of the mineral system according to the obtained values of the pH salt can be divided into two parts: upper - from the ridge to a depth of 20 cm, where the pH ranges from 5.58 to 5.82 and the bottom - from 20 to 50 cm with a pH of 7.28-7.76.

The ambiguity of the obtained values was recorded on the organo-mineral fertilizer system. The pH salt from the ridge to a depth of 20 cm varies within the smallest significant difference - 5.91-6.12.

At depths of 20-30 and 30-40 cm, the values are almost the same - 5.34-5.37 units, and the depth of 40-50 cm is characterized by an increase in the pH of salt to 6.71, which is the largest study in this case.

The soil using organic fertilizer system in terms of salt pH also has a different distribution. The highest pH is in the ridge (5.93), as well as layers of 0-10 and 30-40 cm (5.99 and 5.97), and the lowest - 5.29 at a depth of 40-50 cm.

The average pH salt is from 10 to 30 cm with a value of 5.74.

In the variant without irrigation, we have the same salt pH indicators in 0-20 cm soil thickness - 5.25, and then there is a sharp increase this indicator about in 40% (2.24 units). At the depths of 30-40 cm, the figure increases slightly and reaches a value of 7.81.

Similarly, to the previous described, in the variant of fallow use, the pH salt of the upper 20 cm thickness is the smallest - 5.11-5.17 units. Further, at the studied depth there is some increase first to 5.52 and then to 5.61 at a depth of 30-40 cm. The pH salt of 40-50 cm thick is within the smallest significant difference with the previous figure.

Thus, most of the obtained pH salt values belong to the neutral and close to neutral reaction of the soil solution, slightly less than the analyzed samples show a weakly acidic reaction, and a small amount of it slightly alkaline.

Neutral and close to neutral have the upper ridges and soil thickness from 0 to 20 cm of all variants with the cultivation of garden strawberries. The average alkaline reaction is at depths of 30-40 and 40-50 cm of control variant, mineral system and variant without irrigation. Slightly acidic pH salt in the lower part of the soil of the organo-mineral system and, conversely, in the upper parts of the variants without irrigation, as well as the fallow variant.

CONCLUSIONS

According to the dynamics of the obtained values during the three years of research on the content of water-soluble sodium and calcium, we can state that the sodium content gradually increases in all variants of the experiment, and the amount of calcium decreases. As a result, the ratio of Ca:Na decreases. Therefore, the use of irrigation for three years leads to a significant transformation of the content of water-soluble salts in Calcic Voronic Chernozem of all research variants. None of the analyzed variants revealed water-soluble potassium content, except for single samples.

According to scientific research, higher indicators of electric conductivity for irrigating water loamy soil for strawberry growing is 900 μs/cm. Studies have shown an exaggeration of the electrical conductivity of irrigation water by 242 μs/cm, which can be some negative impact on the yield of strawberry plants.

The use of irrigation also affects soil pH. Most of the obtained pH salt values belong to the neutral and close to neutral reaction of the soil solution, slightly less than the analyzed samples show a weakly acidic reaction, and a small amount is slightly alkaline.

The highest values of water pH were recorded in the lower parts from 30 to 50 cm variants of control and mineral system. The lowest pH in the 40-50 cm thickness of the variant of the organic fertilizer system. All other indicators can be attributed to the average values ranging from 7.15 to 7.94.

Therefore, irrigation with medium saline water for three years during the cultivation of strawberries does not cause a significant accumulation of salts in the soil. However, it caused an increase in water-soluble sodium, a decrease in calcium and a change in pH.

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