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EFFECT OF DEEP LOOSENING OF INTER-ROWS ON PHYSICAL PROPERTIES OF SOD-PODZOLIC SOIL AND YIELD OF ORGANIC POTATO

Abstract. The purpose of this research is to study the effect of deep loosening of row spacings on the physical properties of the soil and yield of organic potatoes. Two variants of soil cultivation were used in row spacings: usual and 25 cm deep. The soil cultivation was carried out with a row-crop chisel cultivator. Its design was developed at the institute. Analysis of the data obtained as a result of experimental studies showed that deep loosening of row spacings had a positive effect on soil compaction both in the inter-row width and directly in the plough ridge. The soil compaction in the row spacing during normal tillage was in average above 20 %, and in the ridge by an average of 13 % compared to deep tillage. The assimilation of moisture by the soil with when using of deep loosening of row spacings also had a positive trend, especially under condition of a large amount of precipitation in a short period of time. Thus, with a loss of 34 mm, the soil in the variant with loosening the row spacings in a larger volume absorbed moisture and the moisture indicators increased sharply in layers, at 15 cm by 27 %, at 25 cm by 20 %, at 35 cm by 5 %. Potato yield increased by 8.7 % when using deep loosening of row spacings. The obtained results of experimental studies should be used as recommendations when carrying out technological operations aimed at caring for potato plantings.

Keywords: deep loosening of row spacings, soil moisture, soil compaction, organic production, potatoes

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ВЛИЯНИЕ ГЛУБОКОГО РЫХЛЕНИЯ МЕЖДУРЯДИЙ НА ФИЗИЧЕСКИЕ СВОЙСТВА ДЕРНОВО-ПОДЗОЛИСТОЙ ПОЧВЫ И УРОЖАЙНОСТЬ ОРГАНИЧЕСКОГО КАРТОФЕЛЯ

Аннотация. Целью данного исследования является изучение влияния глубокого рыхления междурядий на физические свойства почвы и урожайность органического картофеля. В междурядьях использовалось два варианта обработки почвы: обычный и на глубину 25 см. Обработка почвы проводилась с помощью пропашного культиватора-глубокорыхлителя, конструкция которого разработана в ИАЭП. Анализ данных, полученных в результате экспериментальных исследований, показал, что глубокое рыхление междурядий положительно сказалось на уплотнении почвы как по ширине междурядий, так и непосредственно в гребне. Уплотнение почвы в междурядьях при обычной обработке почвы было в среднем выше 20 %, а на гребне в среднем на 13 % по сравнению с глубокой обработкой почвы. Усвоение влаги почвой с использованием глубокого рыхления междурядий также имело положительную динамику, особенно в условиях выпадения большого количества осадков за короткий промежуток времени. Таким образом, при выпадении 34 мм почва в варианте с рыхлением междурядий в большем объеме усвоила влагу и показатели влажности резко повысились в слоях, на 15 см – на 27 %, на 25 см – на 20 %, на 35 см – на 5 %. Урожайность картофеля увеличилась на 8,7 % при использовании глубокого рыхления междурядий. Полученные результаты экспериментальных рекомендуется использовать при проведении технологических операций, направленных на уход за посадками картофеля.

Ключевые слова: глубокое рыхление междурядий, влажность почвы, уплотнение почвы, органическое производство, картофель

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Introduction. Currently, organic crop production is one of the most promising areas. To produce competitive organic products, it is required to use modern machine technologies, including the advanced achievements of biological and engineering sciences, adapted to cultivation of agricultural crops to the local natural and climatic conditions [1–4].

In this regard, the scientists of the Institute for Engineering and Environmental Problems in Agricultural Production conduct comprehensive studies of technological methods of cultivating agricultural crops, including potatoes in an experimental organic crop rotation. The results of the research will allow the formation of sound technical and technological solutions for organic crop production

Unfortunately, when growing organic potatoes using modern technical solutions, it is difficult to achieve high yields and good quality tubers. This is due to the following factors:

– a high degree of effect of natural and climatic conditions with risks difficult to minimize in the organic production of potatoes;

– inability to use most artificial fertilizers;

– inability to use chemical pesticides;

– inability to use chemical weed control agents.

Mineral nutrition of organic potatoes is carried out through organic fertilizers and use of green manure crops in crop rotation, with the complete replacement of artificial fertilizers. There is a great potential in the Russian Federation for organic fertilizers to be used in crop production, including concentrated organic fertilizers (COF) [5]. In the Leningrad region alone, large agricultural enterprises annually produce over 5 million tons of organic fertilizer based on cattle and poultry manure containing over 30 thousand tons of Nitrogen and 6 thousand tons of Phosphorus [6].

Due to inability to use pesticides to protect organic plants, it becomes necessary to replace them with biological agents. The industry of production of biological plant protection products in the Russian Federation annually increases production, the sales market is growing, as is the range of protection products [7, 8].

In order to control formation of optimal physical parameters of soil, continuous monitoring of the soil condition should be carried out. The two main soil parameters are soil compaction and soil moisture. Research at Cambridge showed that potato plants suffer from the dual stress of soil compaction and lack of moisture. At the same time, the growth of potato tubers is delayed [9]. Certain management of these indicators is possible only through the use of rational, science-based technological operations [10].

Based on previous studies, it was found that a rational way to change the physical parameters of soil during growing season of potatoes is deep loosening of row spacing (up to 25 cm).

Thus, the purpose of this research is to study the effect of deep loosening of row spacings on the physical properties of sod-podzolic soil and yield of organic potatoes.

Materials and methods. The field experiment was carried out at the Experimental Station of the Institute for Engineering and Environmental Problems in Agricultural Production (IEEP) – branch of FSAC VIM. The experimental area was located at 59°65’ N and 30°38’ E near the town of Pavlovsk. According to the Russian classification, the soil of experimental plots is sod-podzolic light loamy gleyic on residual carbonate moraine loam. It has a weak acidic reaction (pH 6.5–6.6), high organic matter content (5.6 %), and medium to high levels of available P and K. A field with potatoes is part of an organic crop rotation. Options with potatoes, without compost and with compost based on chicken manure at doses 4 and 8 t/ha were used [11].

For continuous monitoring of the state of organic potatoes field, an information system for its monitoring was developed. It consists of two large subsystems: monitoring the physical parameters of the soil condition and monitoring the climatic parameters of the environment (Figure 1). Titles of protection have been obtained for the submitted software (SW) [12].

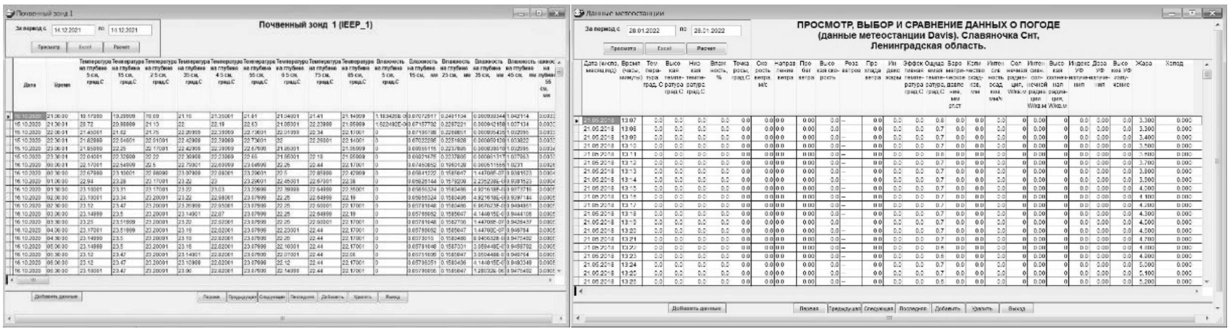

Figure 1. Software interface “Monitoring of physical parameters of soil condition”

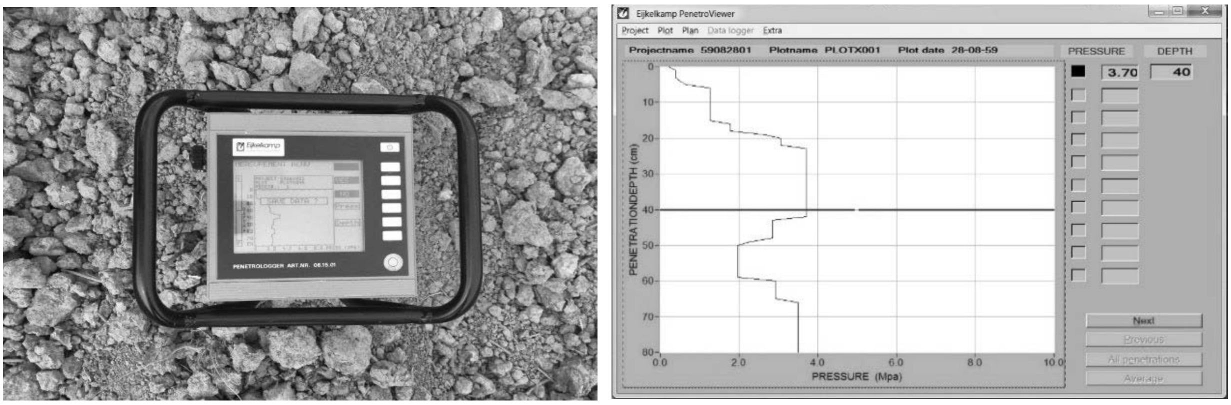

Figure 2. Penetrologger device and software interface

Information coming from a number of measuring instruments, such as weather stations, subsoil measuring system, etc., is accumulated and processed by the developed software. One of the most time-consuming is information on the state of soil compaction. The Penetrologger from Eijkelkamp is currently the most modern soil compaction tester. Penetrologger is an electronic penetrometer with a data logger for recording a continuous texture profile of soil to a depth of 80 cm with a measurement resolution of 1 cm [13]. Extraction and conversion of data takes place through special software PenViewer 4.26.1, and then data is loaded into the developed information system (Figure 2).

Technical and technological decisions on various technological operations used for cultivation of organic potatoes are promptly made based on the results of the information obtained. If overconsolidation of soil is detected, which can lead to decrease in soil moisture, it is required to carry out technological operations to decompress the soil environment. For this purpose, a unique design was developed and an experimental sample of a deep-cultivator subsoiler (Figure 3) for the care of plantings of organic potatoes was constructed at the Institute for Engineering and Environmental Problems in Agricultural Production.

An experimental sample of a multi-purpose deep-cultivator subsoiler consists of the following parts:

– frame;
– with fixed support wheels;
– depth adjustment mechanism for deep-loosening racks;
– hillers are attached to them by leashes, forming a profiled surface.

Rotary needle harrows are attached to the rear of the frame, by leashes, which destroy weeds and break up large clods of soil formed as a result of the hiller work in conditions of high soil moisture. The decrease in the compaction of the cultivated soil layer is carried out due to the formation of intersecting deformation zones inside it between two adjacent deep-loosening racks. A narrow compaction zone at the bottom of the furrow along the trace of the passage of the tool is formed when the soil interacts with the deep-loosening working body. This zone does not prevent the penetration of the root system of plants, as well as absorption of precipitation moisture.

Figure 3. Experimental sample of a multi-purpose deep-cultivator subsoiler

Results and discussion. According to the results of research in 2019–2021, the high efficiency of using the proposed design of a multi-purpose deep-cultivator subsoiler has been proven. Graphs of soil compaction measuring immediately after deep loosening of row spacings, as well as dynamics of soil compaction for the growing season of potatoes in 2020, are presented in Figure 4.

The presented graphical dependences show that deep loosening of row spacings reduces the soil compaction not only immediately after loosening, but this effect continues over time. For example, on July 15, 2020, the soil compaction in the control was 2.4 MPa, in the experiment 1.3 MPa, and on August 15, 2020, the compaction in the control was 1.6 MPa, in the experiment 0.9 MPa. Dependences of soil hardness in farms of the Leningrad region, according to the results of our measurements, are presented in Figure 5.

Analysis of the results showed high soil compaction in the potato fields of farms in the Leningrad Region in 2021. Apparently, during formation of the root system by potatoes on such soils, great efforts will be required to penetrate the roots into the underlying soil layers, where the compaction becomes even higher. Also, absorption of precipitation on such soils is very difficult, with their abundant precipitation; there are great risks of water erosion processes. This can lead to destruction of the formed ridges with potatoes and loss of the crop.

The results of measuring soil compaction indicators in 2021 on the experimental field, directly in the ridge, as well as in the row-spacing of organic potato plantings, are presented in Figure 6.

Deep loosening of soil in 2021 reduced the compaction of soil between the rows in layers to 40 cm unlike in 2020. This is due to the fact that 2021 was characterized by drier conditions with less precipitation in the first half of the growing season. High humidity contributes to soil decompaction, which was not observed in 2021.

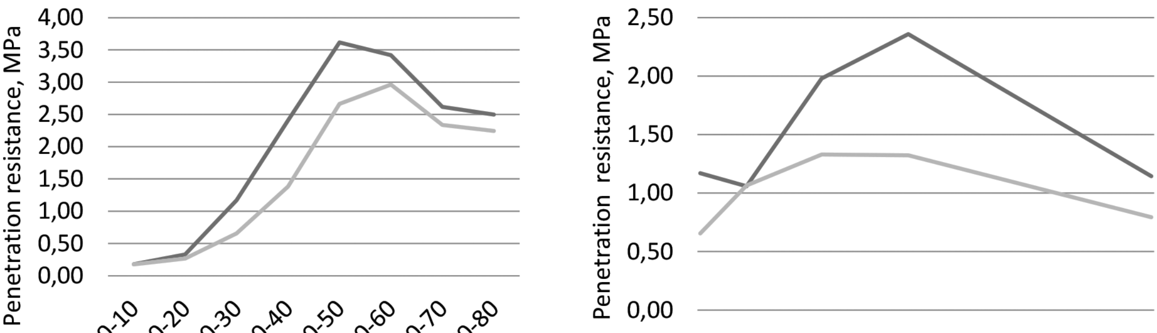

Figure 4. Soil compaction by layers after deep loosening of row spacings

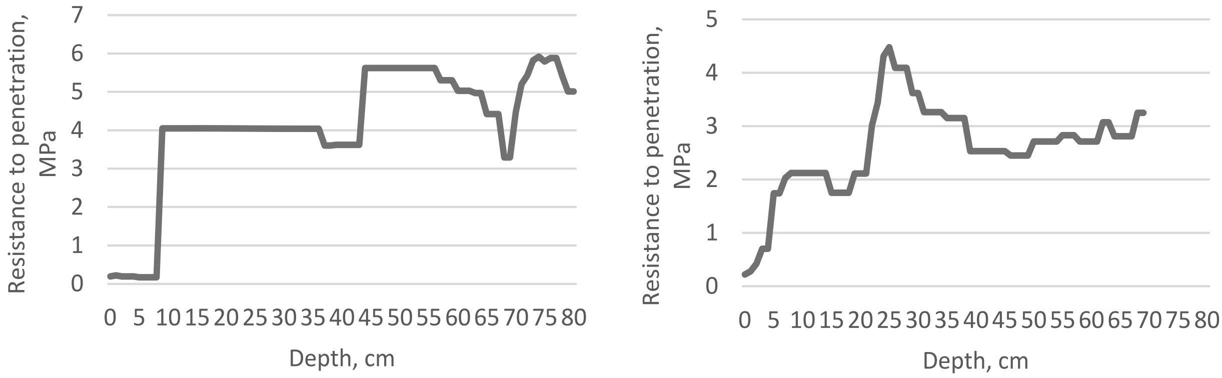

Figure 5. Data on soil compaction in a number of farms in the Leningrad Region in 2021

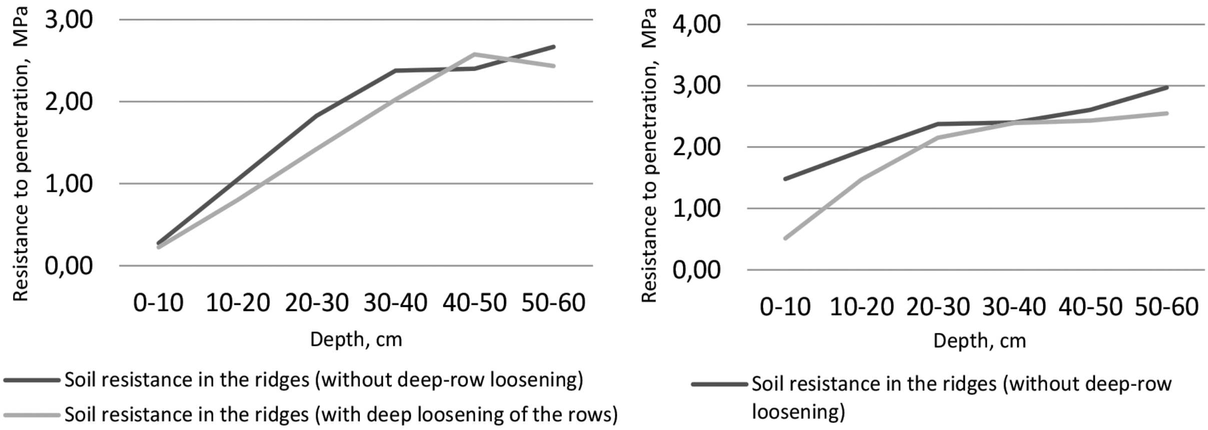

Figure 6. Soil compaction in the ridge and soil compaction in the row

Compaction of soil was on average 20 % higher in the control relative to the experiment, and in the ridge by an average of 13 %, in 2021. The most important result is that in the zone of root formation in the experiment, the soil compaction was 22.2 % lower compared to the control. Graphical dependences obtained during processing of data from subsoil probes are presented in the Figure 7.

Analysis of dynamics of soil moisture by layers indicates dry conditions during the summer of 2021; during the growing season before cutting the tops of potatoes, only 116.8 mm of precipitation fell. In this regard, a sharp decrease in soil moisture in layers up to 35 cm was observed in July. However, soil moisture was almost the same below 35 cm.

Due to extreme temperatures and soil drying up, decision was made to carry out repeated deep loosening of row spacings. However, heavy rains fell immediately after this operation (up to 34 mm in a short period). With a large amount of precipitation, a large amount of moisture was assimilated in the variant with loosening of row spacings, the moisture indicators increased sharply in subsequent layers, 15 cm – 27 %, 25 cm – 20 %, 35 cm – 5 %.

Deep loosening of row spacing also affected the yield of potatoes (see Table). The soil conditions were quite difficult for the development of potatoes in this year. However, on variants with deep loosening, the conditions were formed more favorable. Especially, the second dose of compost significantly increased the yield of potatoes. This dose of compost, accompanied by deep loosening, increased the yield of potato tubers by 67 %, compared with the variant with the same dose, but with normal processing. It should be noted that in 2021, potato yield was significantly lower compared to previous years throughout the North-West region. This is due to the extreme climatic conditions prevailing in 2021.

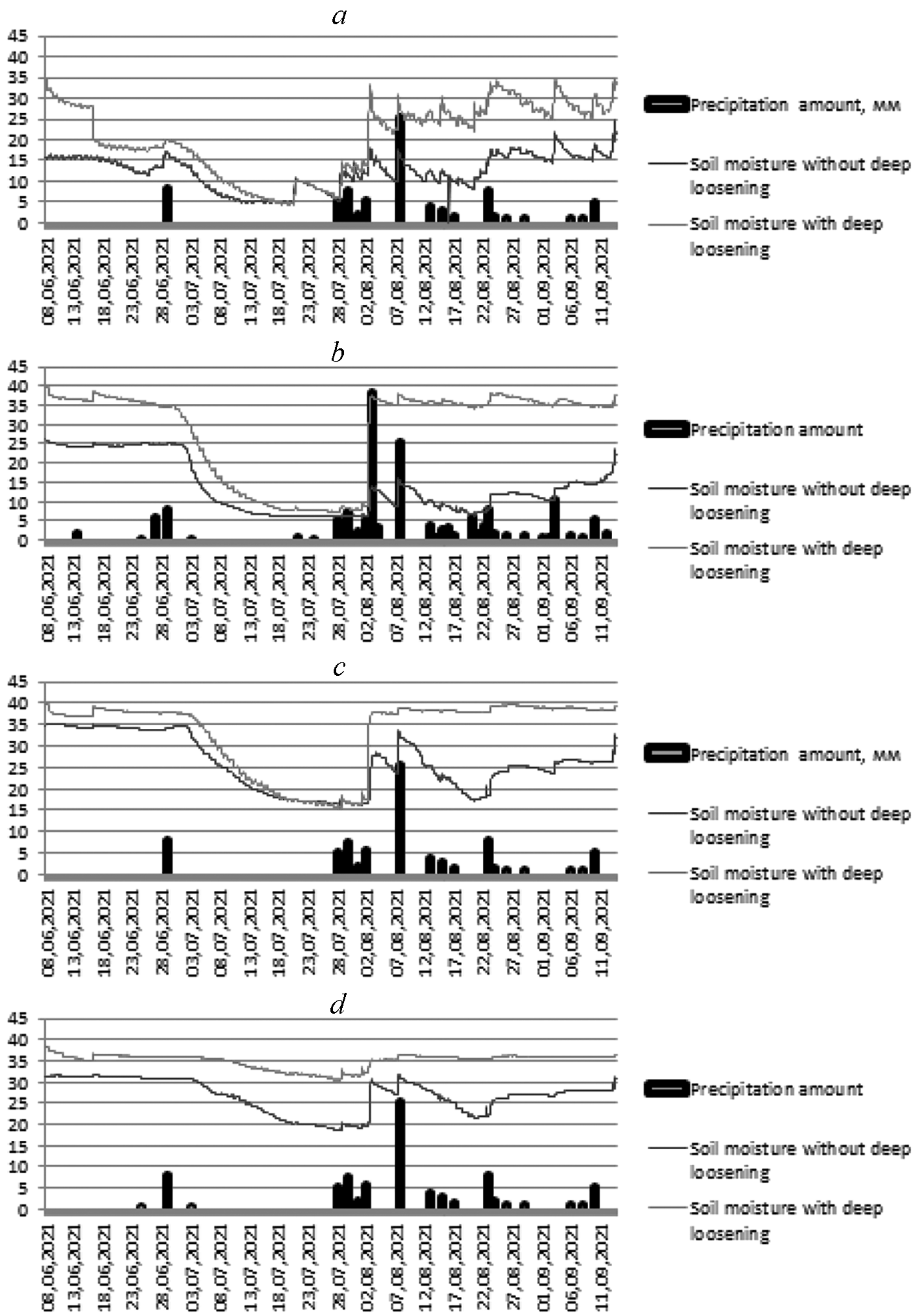

Figure 7. Soil moisture in the following layers: *a* – 5 cm; *b* – 15 cm; *c* – 25 cm; *d* – 35 cm

Compost application and deep loosing effect on potatoes yield

Compost application	Type of cultivation	
T/ha	Normal cultivation	Deep loosing
0	11.9	12.9
4	11.0	13.0
8	15.2	25.4
$LSD_{0.95}$	2.1	

Conclusions. Use of deep loosening of row spacing in potato plantings leads to formation of favorable soil conditions, which generally affect the process of growth and development of tubers throughout the growing season. Deep loosening of row-spacings during cultivation of organic potatoes significantly reduces soil compaction both in row-spacings (by 20 %) and directly in the root formation zone (by 13 %).

Soil with deep loosening of row spacing absorbs moisture better, especially when there is a large amount of precipitation. For example, the amount of precipitation increased sharply in August 2021, which also led to a sharp increase in soil moisture in the following layers, 15 cm – 27 %, 25 cm – 20 %, 35 cm – 5 %.

The proposed technological method significantly increased the yield of potatoes. Thus, the yield of potatoes with the second dose of compost and deep loosening of row spacing was 22 t/ha, which is 66 % more than with the same dose of compost but with conventional tillage.

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