

Digestate plus chlorella: Important alternative biotechnologies for soils and agricultural production in the context of climate change

Rayisa Vozhehova^{1,2}, and Svitlana Petrenko^{1*}, Dilafruz Kholmurodova³, and Gulmira Tursunova⁴

¹Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine, 24 Maiaksa doroha str., Khlibodarske, Odesa Region, 67667, Ukraine

²Western Caspian University, Baku, AZ1001, Azerbaijan

³Samarkand State Medical University, Samarkand, Uzbekistan

⁴Samarkand Institute of Economics and Service, Samarkand, Uzbekistan

Abstract. Over the past decade, the topic of climate change has become an integral part of our everyday life. Significant anthropogenic impact on the environment contributes to the acceleration of this process and leads to catastrophic consequences in some regions. This directs the views of scientists in many industries to the development and implementation of environmentally friendly technologies, waste-free production and the use of non-traditional approaches to the ecology of production, including agriculture. One of the areas that has recently attracted the attention of scientists from many countries around the world is the use of microalgae, among which *Chlorella vulgaris* is becoming increasingly popular, having a wide range of applications. The paper presents the results of the effect of a suspension culture of living cells of the microalga *Chlorella vulgaris*, as well as a suspension preparation of *Chlorella vulgaris* grown on digestate, on changes in the chemical composition of sand and on the sowing qualities of winter wheat seeds of the Shestopalovka variety. A high positive correlation was established between the length of roots and coleoptiles of winter wheat seedlings of the Shestopalovka variety ($r = 0.86$) in the variant with an aqueous concentration of the suspension "Chlorella with Digestat".

1 Introduction

As advanced to long-term observations, climatic zones are shifting to the north and west, heat and droughts are becoming more catastrophic, and many extreme weather events that were previously rare often recur in unusual seasons and locations. This is related to climate change, which affects crop production, the condition of forests and water facilities, livestock and fish farming, etc. Almost all the agricultural areas in Ukraine are in the zone of the risky farming (the area with a natural deficit of rainfall), where there is a constant risk of loss of crop volumes in the too dry year or loss of crop quality in the over-rainy year.

* Corresponding author: petrenko_s_a_@ukr.net

The fluctuations in wheat yield in the south of the country are one of the highest in the world: The actual yield can be up to 30% lower than planned. This is a consequence of increasingly more difficult conditions, fewer precipitations, reduced soil moisture, and lower soil water levels.

However, agriculture, in turn, also has a significant impact on climate change. Thus, in 2018, the share of greenhouse gas emissions from the agro-industry in Ukraine reached 12% and now shows the highest growth trend among all sectors. By 2030, emissions from the sector could increase by 64%.

Agriculture also has a significant impact on the binding (accumulation) of carbon in soil and carbon dioxide emissions because of land use change. For example, the introduction of organic component of soil on the eagle lands and pastors, the conversion of forest lands into agricultural use.

Therefore, in order to prevent future soil fertility losses, complex measures should be developed and implemented that will reduce risks from climate change, and will also contribute to the accumulation of organic matter in soil and increase plant stability to adverse conditions of cultivation.

The way to climate neutrality means the development and use of a whole range of new clean technologies throughout the economy: In transport, construction, production, energy and agriculture. The coming decades will see the greatest industrial transformation of our time. And those who develop and produce the technologies that will underpin tomorrow's economy will have the greatest competitive advantage. The scale of this opportunity is clear for all to see. The International Energy Agency (IEA) estimates that by 2030, the market for clean energy technologies will be about \$650 billion a year, more than three times the level of today. Moreover, climate change is already associated with huge costs, and we have no time to move to a clean economy. The EU is preparing a major transition to clean technology to achieve climate neutrality by 2050. Net technology is now the investment sector in Europe, which is growing most rapidly: In 2020 – 2021 it doubled. We have an urgent need to make this energy transition without creating new dependencies. We have a Green deal Industrial Plan - a plan to make Europe a center of clean technologies and industrial innovations on the way to climate neutrality.

Such measures can be attributed to the use in agriculture of microalgae of the *Chlorella vulgaris* family.

Micro fluidity stands at the beginning of trophic systems, playing the most important role of functioning of the entire biosphere. But lately, their industrial production is becoming more and more important, as they are being used in different spheres of national economy. This is also the production of food, feed, fertilizer, and a new promising direction – biofuel production.

The idea of cultivation of microalgae on an industrial scale arose in Germany in the middle of the last century, when they tried to obtain food oils from diatomized algae (however, selected cultures were characterized by low productivity). Soon green microalgae from the birth of *Chlorella* and *Scenedesmus*, which were mainly cultivated in the following years, attracted the attention of scientists. However, at that time the technological features of microalgae growth were still weak, so their interest in them was temporarily reduced. The renewal of research in the field of industrial cultivation of microalgae has begun since the end of 60-ies, and interest in them does not reach today [1-5].

The industrial growth of microalgae has a half-century history. The obtained biomass is used in agriculture, food industry, perfumery, pharmacology, medicine and other sectors of the national economy. The world alga has about 40 thousand species (in Ukraine – more than 5 thousand species), but the most perspective are the representatives of the families of *Chlorella*, *Dunaliella*, *Scenedesmus*, *Spirulina*. The most productive were diatomic (silicon) algae (Diatoms) and green algae (Chlorophyceae) [6].

2 Literature review

2.1 Directions of application of Chlorella

Many substances contained in chloride are accumulated in its cultural environments – simply to put, in the water in which it grows. Thus, according to the Bulgarian scientist P.I.Stancheva in a cellular mass contains up to 350 different substances, and culture environment up to 310! These are various carbohydrates, proteins, organic and fatty acids, carbohydrates, spirits and air, carbon compounds, vitamins, stubble and other substances with high biological activity, which can be successfully used in medicine and agriculture [3-6].

Microalgae are considered as a promising raw material for bio-diesel fuel. The development of microalgae in culture is a way of mitigating the effects of climatic and seasonal factors of growth, while the formation of strain and productivity enables biomass to be obtained throughout the year. The leaders in this field are the Netherlands, Germany, South Africa and the USA and Australia. Experts from China and Japan are actively searching. Scientists are working on optimization of parameters of biocultivators and bioreactors for active cultivation of biomass of algae and processing of raw materials, search of productive species and strains of algae [7-11].

Chlorella (Fig. 1) in agriculture is a 100% organic highly effective natural biostimulator of plant growth, which accelerates root formation, growth, development and flowering. These algae increase protective properties of plants, antistress resistance at adverse external influences, including drought, acclimatization, transplantation [12-13].

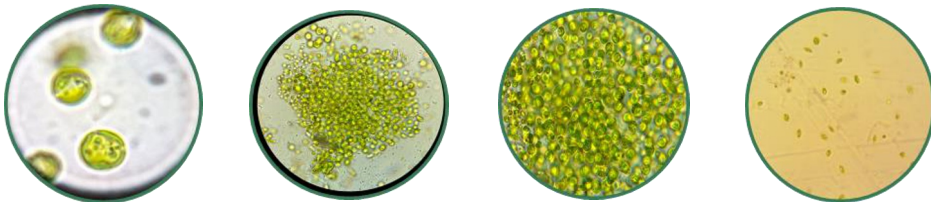


Fig. 1. Chlorella under microscope.

Chlorella is a wonderful green fertilizer. By applying it to watering plants, it is possible to reduce the cost of mineral and organic fertilizers. Algae produce a huge mass of organic matter, enrich water and air with oxygen, is the basis of nutrition for many water and soil animals. A person uses the food, uses it as food for cattle, organic fertilizer and raw materials for the production of various chemical substances and medicinal preparations. Algae participate in formation of sediment and soil formation. Algae in soil composition allocate oxygen to the environment. Organic matter of soil is formed from their dead lattice, which increases its fertility. Therefore, mass reproduction of soil algae – "flowering" of soil, which is observed most often in spring or autumn, consider the purpose of good harvest [3, 5, 6, 13-15].

Agronomically useful soil algae are not only because they actively capture air nitrogen, but also because they are able to produce biologically active substances, including phytohormones and amino acids. They provide optimization of the hormonal state and amino acid composition of plants, which positively influences the production process of agricultural crops [3, 5, 6, 16, 17].

Chlorella is an organic, highly effective natural biostimulator of plant growth, which accelerates root formation, growth, development and flowering. For animal and poultry production, Chlorine is an alternative source of protein, vitamins and amino acids. It contains 40–55% of protein and exceeds even alfalfa. In terms of 1 ha, algae yield 20-30 tons of pure

protein, and alfalfa – 2-3,5 tons. *Chlorella* increases the protective properties of plants, antistress resistance at adverse external influences, including drought, acclimatization, transplantation [3-6, 17].

The expediency of application of *Chlorella vulgaris* is based on very high content of biologically valuable substances in it. The dry biomass of *Chlorella vulgaris* contains more than 45% of crude protein, including irreplaceable amino acids, 30–35% of carbohydrates, 7–10% of fat. In the composition of the green cell contains irreplaceable in nutrition of animals amino acids: Lysine (10 %), methionine (1 %), tryptophan (2 %), arginine (15 %), histidine (3 %), leucin (~6%), jesolycin (~3%), fenilane (~2%), treonin (~2%), valine (~5%), as well as chlorophyll (2%). Vitamins of groups A, B1, B2, B5, B6 , are on the share of vitamins in *Chlorella vulgaris* biomass. Q9, Q12, C, D, E, K, PP); minerals and micronutrients (Ca, N, P, Mg, K, Cu, Fe, S, Zn, Co, Mn, Zr, Rb, I), carotene. In wild strains in native form contains microelements – iodine, bromine, arsenic, cobalt, potassium, phosphorus, iron, magnesium, antibiotics. The cultural environment of chlorides contains a wide number of physiologically active substances, among which are: Growth and development regulators (auxins and hybrids, phenol compounds, natural steroids, vitamins, amino acids); active cell divesters (cytokinina); natural antibiotics "chlorelin", which destroys pathogenic microflora [1-6]

The main advantages of microalgae as organic fertilizers for increasing soil fertility [1, 15]:

- high conversion efficiency of photons (approximately 3-8% against 0.5% for terrestrial plants), which allows to receive higher crops of biomass per hectare), high growth of microalgae cells;
- high carbon dioxide absorption capacity;
- microalgae are not demanding on the quality of water for growth, therefore, sewage, polluted, salty and other waters can be used for their cultivation;
- microalgae can use nitrogen and phosphorus from different sources of wastewater (for example, agricultural effluents, industrial and municipal wastewater) in the process of life, providing an additional benefit of biological wastewater treatment; - for the cultivation of microalgae, it is possible to use arable, desert and saline lands, which are not suitable for agricultural production of food products;
- production is non-seasonal, raw materials can be obtained in batches almost all year round;
- microalgae can be raw materials for a wide range of products (proteins, polysaccharides, pigments, biopolymers, feeds, fertilizers);
- the organization of microalgae biomass production does not require complex equipment and a high level of production automation.

According to O.K. Zolotareva, until recently, microalgae, photosynthetic organisms with a high growth rate, were considered as a source of vitamins, polyunsaturated fatty acids, natural dyes and other valuable biologically active compounds and were cultivated mainly for the needs of pharmacology, medicine, as well as for the enrichment of human and animal diets. With the deepening of the energy crisis, the rapid negative impact on the environment and the actualization of the search for alternative renewable energy technologies, attention to microalgae as energy raw materials and cells with resource-renewing and pathogen-suppressing potential is rapidly increasing [15].

2.2 Microalgae cultivation technology

Microalgae can be grown on an industrial scale in photobioreactors, which are closed, controlled, automated continuous cycle systems that allow for the least costly maintenance

of culture hygiene (Figure 2). Due to the modular design of the equipment, production space is saved [6-8, 17].

Among the main elements of microalgae cultivation technology are:

CO₂ supply: algal biomass contains about 50% carbon on a dry mass, which is asymmetric from carbon dioxide. For production of 100 tons of algae biomass, it is necessary to bind about 180 tons of CO₂, which should be received continuously during the light day. In an open way, the absorption of carbon dioxide comes from the atmosphere. For active growth of microalgae, it is necessary to enrich the mother liquor with a mixture of air and CO₂ and remove O₂. Carbon dioxide can be obtained from a CO₂ cylinder or produced from the exhaust gases of a diesel generator after preliminary cleaning [3-6].

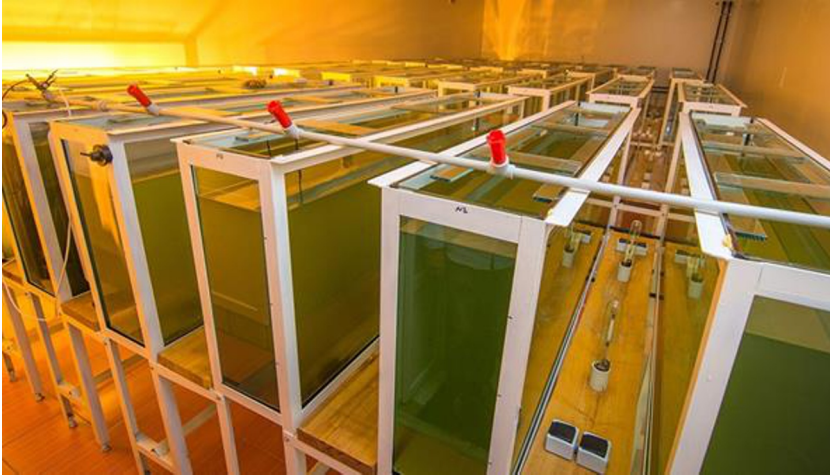


Fig. 2. Scientific and production complex of biotechnology company "Zhyva Chlorella", Ukraine [17].

Growing algae in reservoirs is ineffective, because in ordinary reservoirs surface algae cover the rays of the sun, which are located in the depth. Also, there are problems of water evaporation and appearance of algae-weeds. Therefore, installations now provide for vertical placement of algae [1-6]. **Elements of nutrients:** as rule, a mother liquor solution of nutrients is prepared and added to the water every 10 hours. Burrelli, Chu-13, Tamiya, Bolda and other nutrient media are used [3-6].

Temperature: most algae develop in water bodies at a temperature of 35-40°C, as the temperature rises, their number drops sharply.

Periodically, the culture medium is sent to the filtration line, which is a set of hydro cyclones, where the primary separation of algal biomass from the liquid takes place. The filtrate is returned to the mother tank to prepare the nutrient solution. The algae biomass concentrate is sent to a microwave dryer for drying and then used in various industries [3-6, 17].

2.3 Digestate and directions when its use

Digestate is a product of the bioconversion of organic materials in the process of methane fermentation, as a result of which complex organic substance is dissolved to more simple organic compounds, mineralized substances, microbial biomass and biogas, consisting mainly of methane (55-70%) and carbon dioxide (30-45%). The methane content in biogas largely depends on the raw materials used (corn silage, beet pulp, post-alcohol bard, molasses, cattle manure, chicken manure, etc.) and the fermentation technology [18].

Renewable sources in general, and bioenergy in particular, are growing steadily, outpacing the use of all other fuels. With the right energy policy, Ukraine will have a similar result. At the end of 2020, the share of renewables in the EU was 22%: 12.5% - bioenergy and 9.5% - other RES. This means that today bioenergy is the largest (after nuclear energy) energy sector in the EU with a steady positive development trend. The EU's legally enshrined goal is to reach 45% of energy from RES in 2030, with bioenergy accounting for about half of it [18-19].

For example, Oudon Biogas, which has 72 farms in the Laura region of France, is launching an agricultural biogas project. In April 2022, Oudon Biogas laid the first brick of the plant, which will be built using anaerobic digestion technology and will start operating in 2023. More than 140,000 tons of manure produced on its 72 farms will be recovered. 85 % of the raw materials are agricultural by-products such as manure and straw. Grain waste and local agricultural by-products can also be used to feed the plant. As a result, 55 GWh of biomethane will be produced per year, which is equivalent to the green energy consumption of 9,000 families in the Craon region. The biogas produced will be fed into the French national grid and will avoid emissions of approximately 14,000 tons of CO₂ into the atmosphere, which is equivalent to the greenhouse gas emissions generated by 5,500 cars (with an average distance of 20,000 km per year). The resulting digestate will be used on 7,700 hectares of Oudon Biogaz farms, which will reduce the use of chemical fertilizers [19].

The project will provide farmers with access to digestate, a natural fertilizer with agronomic characteristics that can replace chemical fertilizers.

A typical technology for the production of biogas from agricultural raw materials (manure, litter, corn silage, pulp, crop residues, etc.) is methane fermentation in semi-flow bioreactors (Figure 3) [18].

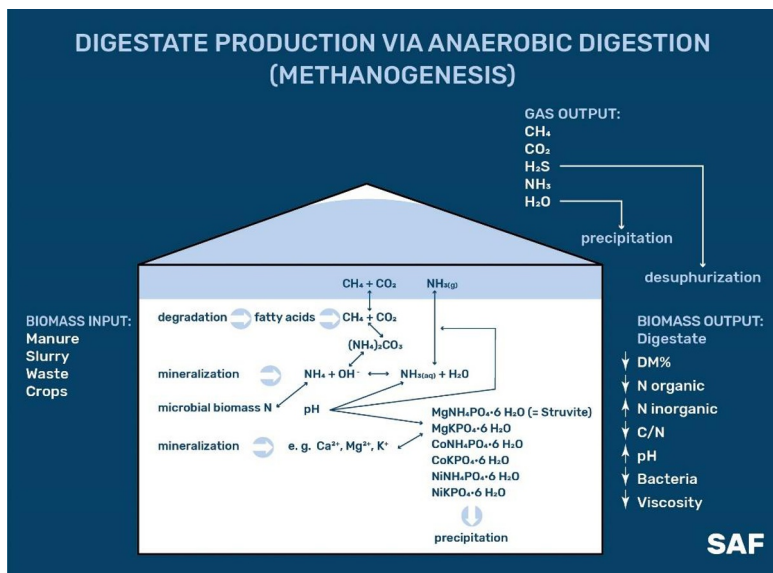


Fig. 3. Production of digestat in the process of methane fermentation [18].

As a result of the breakdown of organic matter, mineralization processes, and the release of biogas, the digestate produced is lower in moisture compared to the feedstock:

- The content of dry matter is reduced and humidity is increased accordingly and the level of strength is reduced. The humidity of the digestate is usually 94-96%, although it can vary in the range of 92-99%.

- The content of ammonia nitrogen (directly available for plant nutrition) increases by 10-70%. The increase in the proportion of ammonia nitrogen depends on its initial content in the feedstock - a smaller increase during fermentation is typical for pig and cattle manure, and a larger increase for food waste and plant material.
- The C/N ratio decreases due to the release of part of the carbon with biogas. The optimal C/N ratio for methane fermentation is 20-30, which is also considered optimal for soil biocenosis.
- The content of pathogenic microflora and viable weed seeds is reduced because of simultaneous exposure to temperature (usually 38-40°C) and acidity in the bioreactor for a long time (at least 25-30 days).

In the process of methane fermentation, part of the organic matter is transformed into biogas, which reduces the content of carbon (C), hydrogen (H), oxygen (O), sulfur (S), and nitrogen (N) in the feedstock. With each 1 m³ of biogas produced, the feedstock loses an average of 502 g of carbon, 114 g of hydrogen, 517 g of oxygen, 5 g of sulfur, and only 0.06 g of nitrogen (Fig. 4).

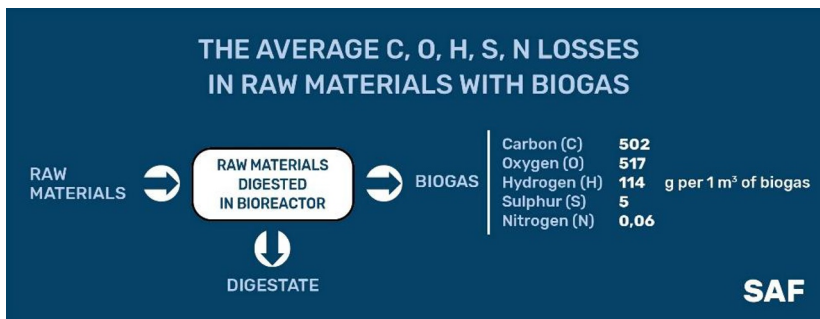


Fig. 4. Average output C, O, H, S, N with selected biogas [18].

A significant portion of the sulfur can be returned to the digestate if hydrogen sulfide removal is provided in the bioreactor's sub-dome space. If biogas desulphurization takes place in a separate facility, the efficiency of hydrogen sulfide removal is much higher, and the resulting sulfur-containing product (in solid or liquid form) can be a marketable product, for example, for the production of complex mineral or organo-mineral fertilizers.

All other input macro- and microelements are contained in the digestate as part of native or converted compounds. Therefore, the chemical composition of the digestate is determined mainly by the mixture of components entering the bioreactor, including raw materials for biogas production and various additives (enzymes, micro-nutrients, reagents, water, etc.).

Thus, digestate has the following characteristics that are important for soils and agricultural production [18-19]:

Contains a complex of macro- and micronutrients necessary for plant growth (N, P, K, S, Co, Mo, Zn, Fe, Mn and others).

It has a high content of readily available nitrogen for plants (60-80% of the total nitrogen content).

It has a balanced C/N ratio (20-30).

It has a pH level close to neutral (6.5-8.0).

It doesn't contain (minimum content of) viable weed seeds and pathogenic microflora (subject to the required duration and temperature of the process).

2.4 Utilization of digestate from biogas plants by cultivation of microalgae

Digestate from biogas plants are also an organic fertilizer that can contain all of the above types of organic materials in a converted form.

Recycling organic materials back into the soil is considered in most cases the best environmental approach to close the natural nutrient and carbon cycles. Organic materials are a valuable source of essential nutrients (such as nitrogen (N), phosphorus (P₂O₅), potassium (K₂O) and sulfur (SO₃)) that are essential for plant growth and thus sustainable crop production. Organic materials are also a valuable source of organic matter that contributes to soil water saturation, facilitates mechanical processing and soil erosion resistance, etc.

At the same time, the return of organic material to the soil should be controlled in terms of both the agrotechnical effect (application should be balanced according to the type and condition of the soil, crops, etc.) and the environmental effect (application should not lead to deterioration of the sanitary and epidemiological situation, soil and groundwater pollution, etc.) Therefore, the use of pretreatment technologies for organic materials is appropriate and, in some cases, necessary.

Anaerobic digestion technology is one of the most efficient ways to bioconvert various types of organic materials, including those of agricultural origin.

Digestate application reduces the potential for soil erosion and improves soil productivity by increasing the organic matter content of the soil and improving its fertility, including through the supply of nutrients. Anaerobic digestion technology is essentially an important link in the recycling of organic raw materials in agriculture.

Digestate is commonly used as a fertilizer for crops without additional processing, thus replacing industrial mineral fertilizers. However, the need for efficient nutrient management, given the limited application of manure in areas with high animal densities, as well as the depletion of global natural phosphorus and potassium reserves, makes the recovery and recycling of nutrients from manure and other wastes increasingly important for farmers, technology providers, investors and decision makers [18-19].

3 Object, subject, and methods of research

For the study, a suspension of *Chlorella* microalgae (TS U 03.0-37613791-001:2017) [24], was used, which meets the requirements of the Organic Standard (certificate No. 21-1088-04) and is suitable for use in organic agriculture in accordance with the Standard of International Accredited Certification Bodies for organic production and processing, which is equivalent to European Union Regulations No. 834/2007 and 889/2008 [21].

The biotechnology company RPC Zhyva *Chlorella* (U Samvela Farm, Ukraine) grew *Chlorella* microalgae in the form of a suspension on the digestate of biogas plants produced in Moldova and produced a new type of organic fertilizer - *Chlorella* Suspension PLUS Digestate. The product was tested in the laboratory and in the field on cereals, green vegetables (sorrel, dill, parsley, coriander, spinach, and radish) and nut crops (almonds, hazelnuts).

In order to establish the effect of using the microalgae *Chlorella*, which was growing on digestate, we conducted an experiment that included the following stages:

The first stage involved several sand treatments to determine the best accumulation of organic matter in the sand, followed by the determination of nitrogen, phosphorus, potassium, organic matter, pH, and sulfur:

- 1st Variant - without treatment (control)
- 2nd Variant - water treatment
- 3rd Variant - *Chlorella* Start treatment

4th Variant - Chlorella Plus treatment (digestate)

The determination of nitrogen, phosphorus, potassium, organic matter, pH and sulfur in the respective samples was carried out at the laboratory of the testing center of the Odesa branch of the State Institution "Institute of Soil Protection of Ukraine" [22].

The second stage involved the treatment of winter wheat seeds with a suspension of chlorella microalgae, followed by their germination:

1st Variant - water treatment (control)

2nd Variant - treatment with Chlorella Start

3rd Variant- treatment with Chlorella Plus (digestate)

Object of research: germination processes of soft winter wheat seeds depending on the treatment of seeds with Chlorella suspension on different nutrient media.



Fig. 5. Digestate



Fig. 6. The microalgae *Chlorella vulgaris*'s subcellular culture of living cells



Fig. 7. Suspension Chlorella plus digestate

Subject of research: winter wheat variety Shestopalivka, germination energy, laboratory germination of seeds, root length and colloid of winter wheat seedlings

Laboratory studies were conducted in the laboratory of the Department of Field and Vegetable Crops of Odesa State Agrarian University. Both well-known scientific methods (experiment, analysis, hypotheses) and special methods (laboratory, comparative, calculation and statistical) were used in the research.

4 Results

The Odesa branch of the State Institution "Institute of Soil Protection of Ukraine", the testing center, conducted a study of the effect of the suspension culture of live cells of microalgae *Chlorella vulgaris* on sand, which was taken as a zero substrate (Table 1) [22].

The pH value of the control variant was 7.1, compared to the experimental variant, where a suspension of Chlorella was introduced, which had a pH of 7.7 during the growing season.

The data of the research results obtained in the course of the work convincingly proved the uniqueness of the properties of the microalgae Chlorella as a natural biostimulant of plant growth and development.

Therefore, another form of chemical action of microalgae on the soil is changes in its pH. It is known that algae, assimilating carbon dioxide in the course of their life, alkalize the environment, which is observed in natural water bodies, in culture, and in soils. Since microalgae are unevenly distributed in the soil, significant soil alkalization by microalgae

occurs in places where they accumulate, where conditions are particularly favorable for their development.

Table 1. Influence of the treatment of suspended culture of living cells of microalgae *Chlorella vulgaris* on the change of the chemical composition of the sand

№	Indicator, determined, od. see	In fact				Marking of the normative document on the test method
		№ 1 sand control	№2 water control	№3 Chlorella Start	№ 4 Chlorella Plus Digestate	
1	Nitrogen, mg/kg	3,02	2,42	0,85	2,36	MU QINAO.M.-2984*
2	Phosphorus, mg/kg	24,04	19,52	75,39	31,68	GSTU 4114-2002
3	Potassium, mg/kg	111,8	59,52	125,2	135,3	GSTU 4114-2002
4	Organic matter, %	0,57	0,39	0,39	0,39	GSTU 4289:2004
5	pH	7,1	7,5	7,6	7,7	GSTU ISO 10390:2007
6	Sulfur, mg/kg	47,84	49,47	12,99	55,66	GSTU 8347:2015
7	Moisture, %	2,38	0,76	1,94	3,22	GSTU 12536-79

*Methodical guidelines for the determination of heavy metals in agricultural soils and crop production (1992).

Table 2. Influence of processing of winter wheat seeds of the Shestopalevka variety by suspension culture of living cells of microalgae *Chlorella vulgaris* on native quality in laboratory conditions, 2022.

Options for investigation	Energy of germination of seeds, %	Similarity of seeds, %	Length of prophets		Length of roots		Number of roots	
			sm	% before control	sm	% before control	pcs	% before control
1. Monitoring (Water)	12.0	86.0	4.5	100.0	5.0	100.0	3.0	100.0
2. Chlorella START®	46.0	100.0	11.0	244.0	15.5	310.0	4.5	150.0
3. Chlorella plus Digestate®	44.0	100.0	9.5	211.0	13.0	260.0	5.0	166.6

At the second stage, the seeds of winter wheat of the Shestopalovka variety were germinated. After treatment with a suspension culture of living cells of the microalgae *Chlorella vulgaris*, the germination of seeds was determined according to GSTU 41382002 "Seeds of agricultural crops. Methods for determining quality" (Table 2, Figs. 8, 9). The stimulating effect of an aqueous solution of chlorella suspension on the germination energy and laboratory germination of winter wheat seeds of the Shestopalovka variety was established.

Under the influence of an aqueous solution of chlorella suspension Start, the length of winter wheat roots increased by 3.7-40.5% depending on the variety.

A high positive correlation between the length of roots and cotyledon of winter wheat seedlings of Shestopalivka variety ($r = 0.86$) in the variant with aqueous concentration of *Chlorella Plus Digestate* suspension was established.

In order to stimulate the germination of soft winter wheat seeds of Shestopalivka variety, it is necessary to carry out pre-sowing treatment of seeds with a solution of chlorella suspension plus digestate.



Fig. 8. The holding of long castles of the wheat collection of soft winter variety Shestopalovka.



Fig. 9. Effect of the processing of the seeds of the suspension of chlorin on the length of wheat collection of soft winter variety Shestopalovka, (on the left – variant with the processing of chloride plus digestate, on the right - control).

5 Conclusions

The developed agricultural sector of Ukraine with a large amount of agricultural land requires significant amounts of fertilizers. Over the years of Ukraine's independence, the forms of management and land tenure have had a negative impact on soil fertility. This is manifested in the loss of a significant portion of humus, imbalance in the content of nutrients, acidification and alkalization of soils, deficiency of mobile forms of phosphorus, potassium and a number of microelements. Over-compaction, chemical and radiation pollution, and various types of erosion are also revealed. The reasons for this state of soils are, in particular, intensive production with the predominant use of mineral fertilizers and a critical reduction in the use of organic fertilizers. All these phenomena require immediate intervention and efforts to restore soil fertility, so the effective use of organic materials, in particular chlorella suspensions and digestate based on them, is extremely relevant in Ukraine.

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