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Cavitation technology for the production of bionutrients from coprolites and evaluation of their effectiveness

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Abstract. The article presents the results of the development of a technology and a production line for the production of bionutrients for use in crop production in order to increase plant resistance to adverse climatic factors and reduce doses of pesticides and mineral fertilizers. The technology is based on the bioconversion of organic animal waste into coprolites (biohumus), uses the nutritional activity of earthworms. and this is a kind of solid-phase fermentation, where the fermented mass is a heterophase system of the type: solid phase - liquid - gas. Compost as the basis for the vital activity of earthworms is prepared by accelerated biotechnological processing of animal manure and other organic materials. Nutrients are converted by worms into coprolites - forms available to plants.. The humus of coprolites differs in chemical composition from humus formed in the soil with the participation of microflora, in that polymerization processes of low molecular weight decomposition products of organic substances develop in the digestive canal of worms and humic acid molecules are formed. The resulting product was tested for effectiveness on winter rye crops. A noticeable increase in resistance to climatic factors and an increase in yield while maintaining high nutritional qualities is shown.

1 Introduction

It is difficult to ensure an increase in the level of food and environmental security, the need for efficient use of energy and mineral resources without the biologization of crop production [1-3].

Among the bionutrients, there is a group of substances of organic nature of natural origin, called coprolites (biohumus) - products of the vital activity of red California worms (EiseniaFoetida). In the production of coprolites, as a rule, three tasks are solved: environmentally friendly disposal of animal waste, the production of vermicompost and the production of unique feed additives for animals in the form of biomass of red California worms [4-8].

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In the course of numerous laboratory and field experiments with humic substances of various origin, it was shown that humic substances of coprolites have a stimulating and adaptogenic effect at the cellular and subcellular levels [7-10]. The coprolites of worms of the natural population contain 11-15% of humus per dry substance. The humus of coprolites differs in chemical composition from humus formed in the soil with the participation of microflora by the fact that polymerization processes of low molecular weight decomposition products of organic substances develop in the digestive canal of worms and humic acid molecules are formed. These acids enter into complex compounds with the mineral components of the soil, forming stable aggregates that persist in the soil for a long time...

However, many authors note the instability of the properties of biohumus coprolites: they reduce the effectiveness of their action in dry climates, at elevated temperatures [9-11]. This may be due to the special, original structure of humus substances of coprolites, as well as the nature of their connection with the mineral part [9]. Taking into account the warming of the climate, such conditions are becoming the norm in many soil and climatic zones of the country, which means that plants will increasingly need stable stimulation and support of metabolic processes.

A possible reason for the instability of the effect from the use of humicbionutrients may be the special original structure of humic substances of coprolites, labile forms of which may have a non-trivial structure, probably their somewhat closer relationship with the mineral part of the soil also takes place [9]. It is also necessary to take into account the ability of humic molecules to form stochastic compounds of molecules whose sizes reach up to 500-1500 nm. If we proceed from the known pore sizes in the cell wall of roots and leaves of plants, which vary from 3.5 to 5.2 nm., then we can assume that with the length of molecules 5.3-6.4 nm for fulvic acids and 9.4-10.7 nm for humic acids, and even longer conglomerates of their molecules, the transfer of these compounds to cell walls are severely obstructed [3].

For many years, this problem has been solved by combining chemical and physical effects on products containing humic substances: coal, peat, sapropel [5,7]. A number of researchers have come to solve the problem of stabilizing the properties of humic substances by obtaining biohumus by accelerated biotechnological means in the process of processing organic animal waste by annelids into coprolites (biohumus) [2,3]. But even this does not completely solve the problem of the dimensionality of humic substances.

To organize the production of stable quality bionutrients without the use of chemical reagents, a proven technology and an appropriate processing line are needed, which can use local raw materials available in most regions and be reproduced in conditions of both industrial production and agricultural enterprises.

The purpose of the study: to develop a technology and a production line for the production of bionutrients based on the processing of animal waste into coprolites and the use of cavitation to increase their biological efficiency and to identify the effect of the resulting bionutrient on plant productivity in difficult soil and climatic conditions on the example of winter oats.

2 Materials and methods

A method has been developed for obtaining bionutrients by biological processing of organic matter by annelid worms into biohumus and subsequent crushing of conglomerates of humic substances of biohumus into low-molecular fragments by physical action on them by ultrasonic vibrations or pulsating ultrahigh pressure in a hydrodynamic cavitator [3,12].

The technology of bioconversion of organic waste into biohumus (coprolites) is based on the nutritional activity of earthworms and is a kind of solid–phase fermentation, where the fermentable mass is a heterophase system of the type: solid phase – liquid - gas.

3 Results and discussion

Compost as a basis for the vital activity of earthworms is prepared by biotechnological processing of animal manure and other organic materials into the products of the vital activity of earthworms – coprolites.

The technological process begins with the fermentation of fresh manure, for which the manure is pre-laid in a fermenter or in burts. The substrate is prepared from a mixture of fermented manure, soil, straw cutting and, if necessary, with a small addition of lime flour to ensure the acidity of the medium within pH 6.5 ... 7.5. Trays are filled with the resulting substrate, after which the substrate is moistened by spraying water through nozzles to an optimal humidity of 70...80% and is inhabited by worms with a density of about 3-5 thousand individuals per 1 square meter. The best temperature for worm activity is 20...25 degrees Celsius. To maintain humidity, the contents of the trays should be periodically moistened.

The substrate is covered with a cloth of breathable material. Nutrients are transferred by worms mixing organic matter with mineral matter into coprolites: soil matrix humus fixed on the surface of soil particles. Special glands of worms produce phytohormones, enzymes, vitamins, as well as biogenic calcium, which is not contained in compost.

Next, the biomass of coprolites is mixed with water and the resulting suspension is subjected to cavitation. As a result, a colloidal suspension of crushed humates is produced. For this purpose, cavitation installations are sequentially included in the technological process: hydrodynamic and ultrasonic.

For practical implementation, a technology and a project of an experimental technological line for their production in industrial volumes have been developed.

The main factors determining the technological efficiency of hydrodynamic rotary cavitation-acoustic pumps are: high hydrodynamic gradients, high amplitude and high frequency pressure pulsation, the phenomenon of cavitation itself and its accompanying effects. In addition, hydroacoustic rotary radiators have a significant pumping effect, which makes it possible to create energy-efficient technologies and obtain controlled operating modes without the use of back-up pumps. Cavitation created by hydrodynamic generation of intense acoustic waves is the main factor of high-potential energy impact on technological processes.

A suspension of vermicompost pumped by a cavitator pump is also a technological medium that perceives this effect. When an overpressure pulse propagates in the pump stator channel, a short-term low-pressure pulse occurs after it, inertial forces create tensile stresses in the liquid, which causes cavitation. The cavitation efficiency can be regulated by the rotor speed, changes in the static pressure in the stator chamber, the flow rate of the medium, the multiplicity of circulation, the temperature of the liquid and other methods.

Next, the suspension of vermicompost passes through an ultrasonic cavitpator. The operation of the ultrasonic reactor is based on the excitation of ultrasonic cavitation in a thin layer of processed aqueous suspension of vermicompost pumped through the reactor.

From the ultrasonic generator, the voltage of the ultrasonic frequency is supplied to an ultrasonic transducer that converts the high-frequency voltage into mechanical vibrations of the ultrasonic frequency.

When the emitter oscillates with an ultrasonic frequency in the liquid medium of a suspension of coprolites (biohumus) processed in the reactor, alternations of compressions and stretches occur, which create an additional pressure change in it relative to the constant static pressure in this medium.

As a result, an effect closely related to sound pressure is observed in an aqueous suspension of vermicompost, called ultrasonic cavitation, which is understood as the formation of vapor-gas (cavitation) cavities in a liquid medium in the phase of negative sound pressure of acoustic vibrations of ultrasonic frequency, followed by their slamming in the phase of positive sound pressure with the formation of shock waves.

At the first stage, the cavitation cavity expands from the initial vapor-gas embryo (always in large quantities in the liquid), due to a decrease in pressure (stretching phase) in the liquid when exposed to the negative phase of sound pressure.

This process is determined by the difference between the values of the variable sound pressure Rvv(t) and the constant static pressure Pct.

At the second stage, the process of slamming the formed cavitation cavity occurs under the influence of a positive phase of sound pressure (compression phase). This process is determined by the sum of the values of variable sound pressure and constant static pressure.

As a result, the process of closing the cavitation cavity occurs at a speed of movement of the cavity wall of about 250 m / sec. At the same time, the vapor-gas mixture, always located inside the cavity, is compressed under normal conditions to a pressure of 3000 atm., and the temperature inside the cavitation cavity reaches a value of 6000 deg. Kelvin.

At the third stage, the process of secondary expansion of the cavitation cavity begins due to the fact that the vapor-gas mixture compressed to several thousand atmospheres causes the cavitation cavity to rapidly expand at a speed of 250 m/sec. This stage can be identified with a point explosion.

In the process of cavitation treatment, the energy released during the collapse of cavitation bubbles is used to break chemical bonds between atoms of large molecules of humic compounds caused by the physical destruction of molecules and the ionization process. As a result of these processes, activated particles accumulate in the system: radicals, ions, ion-radical formations [1-3].The results of crushing humates are shown in Fig. 1

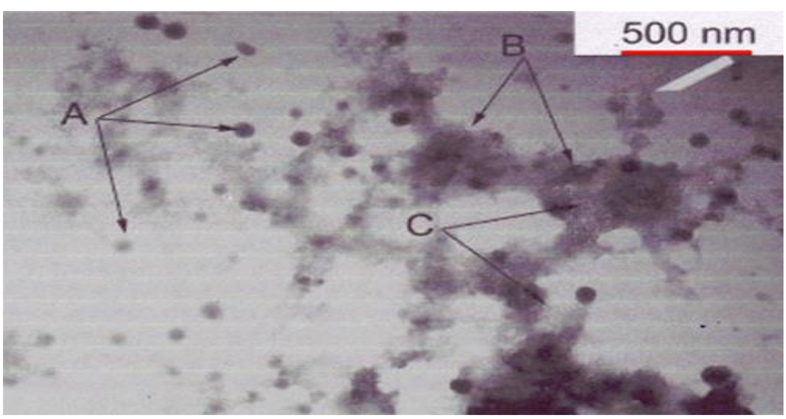

Fig. 1. Humates after crushing

At the last stage, the colloidal suspension of humates is mixed with trace elements and natural biologically active substances or their synthetic analogues, for example, well-known natural auxins and gibberlins or their organomineral analogues (1-chloromethylsilatran, mival), as well as essential trace elements that are key for this culture.

For example, to enhance the effect, an organosilicon compound was introduced into the bionutrient: 1-chloromethylsilatran (Fig.2.). Despite the fact that silicon is one of the most common elements in nature (its content in the earth's crust is 27.6%), many plants (corn, winter and spring grains, legumes, perennial grasses) lack silicon, which is due to the poor availability of its natural forms to plants [13].

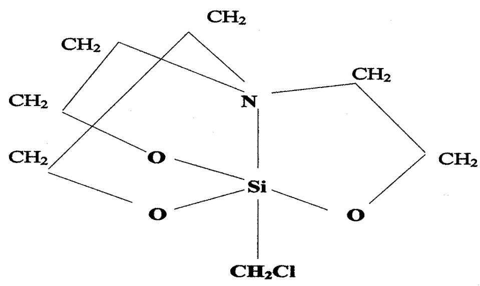

Fig.2. Structural formula 1-chloromethylsilatran

For the practical realization of the possibilities of new bionutrients, a technology and a project of an experimental technological line for their production in industrial volumes have been developed. The production technology implemented in LLC NPC "New Technologies" provides for the preparation of raw materials from coprolites, the preparation of an aqueous suspension and the production of a bionutrient according to the technology described above.

Studies have shown that this made it possible to stably stimulate metabolic processes, and by preserving up to 60% of humic substances in the state of high-molecular groups, it was possible to preserve the effect of protecting the cell from xenobiotics and heavy metals [12-15]. The general result of the described interactions of humic fertilizer substances with living cells is both the stimulation of competent genes responsible for growth processes and the release of energy, which, instead of being spent on compensating for the adverse effects of the external environment, can be spent by the cell on growth and reproduction, which ultimately leads to an increase in the competitiveness of this organism.

As a result, humic substances of the new bionutrient stimulate biochemical processes during seed germination and root formation, which allows plants to form a powerful root system that goes deep into the soil layers, providing plants with additional moisture and nutrients, which is of great importance in conditions of arid climate and low soil productivity. The chemical composition of the resulting bionutrient is presented in Table 1.

Table 1. The composition of the bionutrient ABT- Plant

Nameoftheindicator	**Unitsofmeasurement.**	**Scientific and technical documentation for the test method**	**Testresult**
PHYSICO-CHEMICAL INDICATORS			
pH	pH	GOST 27979-88	8.5
Dryresidue	g/l	GOST 26713-85	19.17
Commonnitrogen	g/l	GOST 26715-85	0.77
Phosphorustotal	mg/l	GOST 26717-85	387
Potassiumtotal	mg/l	GOST 26718-85	4624
Organicmatter	g/l	GOST 27980-88	10.29

Totalcarbon	g/l	GOST 26213-91, Isolation of humic acids by the method of M.M. Kononova, N.L. Belchikova Fulvic acids The sum of humic and fulvic acids	4.72
Carbonofhumica cids	g/l		0.87
Humicacids	g/l		1.63
Carbonoffulvica cids	g/l		3.85
Fulvicacids	g/l		8.67
The sum of humic and fulvic acids	g/l		10.29
THE CONTENT OF CHEMICAL ELEMENTS			
Copper	mg/l		0.51
Zinc	mg/l		289.0
Cobalt	mg/l	Methodical instructions on the determination of heavy metals in the soils of farmland and crop production. - M.: CINAO, 1992	52.84
Manganese	mg/l		540.7
Chrome	mg/l		0.96
Magnesium	mg/l		278.5
Molybdenum	mg/l		668.9
Iron	mg/l		153.7
Boron	mg/l		1.02

Field tests of a new bionutrient with the symbol ABT- Plant as a bioregulator of plant growth and development and an anti-stress bionutrient were carried out in difficult agro-climatic conditions of the Kirov region. The peculiarity of this region lies in the relatively low level of soil fertility (humus content on average 2.3%, mobile phosphorus – 119 mg / kg, exchangeable potassium – 121 mg/ kg); low biological activity and increased acidity of the soil environment (pH = 5).

The natural and geographical conditions of the Kirov region are unique in terms of the duration of the winter period (160...180 days) and the abundance of snow (60...90 cm), and are also characterized by a reduced temperature regime in the summer and winter months. In recent years, soil and air drought has been manifested during the formation and filling of grain.

All these factors significantly reduce the adaptogenic properties of agricultural plants and their resistance to a complex of unfavorable abiotic factors, contribute to the increased development and harmfulness of pathogens of fungal and bacterial diseases.

In such conditions, crops of grain crops are annually affected by root rot, fusarium of the ear and leaves, leaf spots of various etiologies, olive mold, alternariasis. Resistance to non-specific infections is determined not so much by the host genotype as by the physiological state of plants and environmental conditions. In this regard, special attention should be paid not to the pathogen, but to the host plant in terms of optimizing the growing conditions of the crop.

Among grain crops, winter rye is of particular strategic importance in the Northeastern region of the Non-Chernozem zone of the Russian Federation, occupying up to 35% in the structure of grain crops.

Obtaining a consistently high yield of this crop in the Kirov region requires solving the following main problems:

- improvement of the phytosanitary condition of crops and grain;
- obtaining high-quality, biologically complete and environmentally safe food and feed grains;
- improvement of cultivation technology.

The aim of the research is to develop a technology for cultivating winter rye and oats using the bio-nutrient ABT-Plant.

Research objectives:

- to identify the effect of the bionutrient on yield and to determine the contribution of biometric indicators of plant productivity to the harvest;
- to study the effect of biologically active substances on the main indicators of grain quality.

To implement the tasks set, the following observations, records and analyses were carried out using well-known methods.

1. Accounting for laboratory and field germination, sowing density and plant development of winter rye (biometrics of the root system and green mass of plants during the growing season) – GSI methodology, 1985.
2. Phenological observations – GSI Methodology, 1985.
3. Assessment of the phytosanitary condition of winter rye crops; consideration of the spread and development of diseases.
4. Assessment of resistance to lodging and the general condition of plants and crops before harvesting – GSI methodology, 1985.
5. Crop accounting and crop structure analysis – GSI Methodology, 1985.
6. Evaluation of the main indicators of grain quality: protein content, fat content, the indicator "number of drops", grain nature, weight of 1000 grains.
7. Microbiological analysis of grain.

The research material was a bionutrient based on activated humates from earthworm coprolites with the addition of 1-chloromethylsilatran – ABT-Plant (5g/l). The objects of study were: winter rye (Vyatka 2) and diseases (root rot, fusarium of the ear and leaves, types of rust, rhinchosporiosis, septoria, etc.).

The scheme of field experiments is presented in Table 2. The registered area of plots of 20 m^2 (winter rye), the repetition is 3-fold. The placement of plots in experiments is randomized.

Table 2. Scheme of experience for studying the effectiveness of a bionutrientABT- Plant on winter rye

No	**Processing option**	**Agrotechnical term acceptance**	**Purpose of agricultural acceptance**
1	2	3	4
1	Withoutprocessing	–	Control – comparison of experimental options
2	Processing of crops	Springtillering	An experimental option is to study the productive,

	ABT- Plant, at the rate of 1l of the drug per hectare.(working fluid consumption 260 l/ha)		adaptive, fungicidal properties of a bionutrient
3	Processingofwheat	2nd internode	Etalon – chemical control in the assessment of lodging resistance
4	Processing of ABT- Plant crops at the rate of 1l of the drug per hectare.(working fluid consumption 260 l/ha)	earing	An experimental option is to study the yield and fungicidal properties of a bionutrient
5	Processing of ABT- Plant crops at the rate of 1l of the drug per hectare.(working fluid consumption 260 l/ha)	Tilleringandearin g	An experimental option is to study the yield and fungicidal properties of bio nutrients with multiple applications

4 The effect of the ABT-Plant bionutrient on the yield of winter ryeand methods of its application

The growing conditions of grain crops in the Kirov region were generally favorable. Good overwintering of winter rye (90... 100%), sufficient precipitation and relatively uniform precipitation, close to optimal temperature conditions contributed to good grain filling and the formation of a sufficiently high yield. However, the same agro-climatic conditions were favorable for the development of fungal infection on crops.

On winter rye, almost 100% spread of rust infection (brown, stem, crown types of rust) was noted with a high (> 40%) level of disease development. Therefore, the main limiting factor of yield is the deterioration of the phytosanitary situation on crops due to the strong development of rust. Another factor affecting crop formation and product quality is a decrease in plant resistance to lodging due to heavy rains and large plant biomass in agrocenoses.

Against this background, the effect of fungicides and biologically active substances on yield was ambiguous.

In experiments with Vyatka 2 winter rye, the highest yield was obtained when crops were treated with a Tse-Tse-Tse retardant (36.5 c/ha) and in a variant with 2-fold use of the ABT-Plant bionutrient (36.2 c/ha) (Table 3).

Table 3. The effect of the ABT-Plant bionutrient on yieldwinter rye Vyatka 2 (average of 3 repetitions)

Number of plots	**Option**	**Productivity**		
		z/ga	**+/- to control**	**% +/- to control**
1	Control – without processing	33.3	-	-
2	Rocessing of crops ABT-Plant (tillering)	29.6	-3.7	89

3	Treatment of crops with a retardant (2nd internode)	**36.5** *	+3.2	109
4	Processing of crops ABT-Plant (earing)	34.1	+0.8	102
5	2-fold processing of ABT-Plant crops (tillering and earing)	**36.2** *	+2.9	108
	HCP_{05}	2.8		

* – reliable to control at P > 0.95 %

In these variants, higher resistance of plants to lodging was noted: 2.8 and 3.7 points.

Thus, it is possible to make a preliminary conclusion or a reasonable assumption that 2-fold treatment of crops with a bionutrient of winter rye Vyatka 2, contributed to a significant increase in the yield of this long-stem variety.

The influence of the ABT-Plant bionutrient on some indicators
of the quality of winter rye and oat grain

Solving the problem of grain quality aimed at increasing the nutritional value and improving its technological properties is one of the main tasks of breeding and technology of cultivation of agricultural crops.

The content of protein and essential amino acids in oat grain is the main indicator of the nutritional value of this crop. One of the main features that determine the technological properties of oat grain is the fat content in it, as well as the filminess, which ensures the manufacturability of food and dietary grain production.

It is known that grain quality indicators can largely change under the influence of crop cultivation conditions.

In our studies, some positive correlations were found between the signs of rye grain quality and the use of the biologically active bio-nutrient ABT- Plant (Table 4)..

Table 4. Variability of some signs of rye grain quality during the treatment of seeds and crops with the ABT-Plant bionutrient

Processingoption	**WinterryeVyatka 2**		
	Weightof 1000 grains, g.	**The number of grain drops, s**	**Proteincontent, %**
Control – withoutprocessing	25.8	119	10.93
Processing of crops ABT-Plant (tillering)	25.4	123	11.02
Processing of crops ABT-Plant (earing)	24.8	120	11.08
2-fold processing of ABT-Plant crops (tillering and earing)	26.3	106*	**12.10***
treatment of crops with a	25.6	135*	11.02

retardant			

* - reliable to control at P > 0.95 \

5 Conclusion

Thus, it can be reasonably concluded that 2-fold treatment of crops with the ABT- Plant bionutrient of winter rye Vyatka 2, contributed to a significant increase in the yield of this long-stem variety. Two-time treatment of winter rye crops with the ABT-Plant bionutrient caused a decrease in the "number of falls" indicator. Perhaps this is due to the increase in grain size in this variant. As you know, there is a fairly close negative relationship between these signs. However, in this variant, a grain with a high protein content was obtained.

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