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Microbiology

Towards the Biological Activity of the Natural Zeolite – Clinoptilolite-Containing Tuff

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ABSTRACT. This paper discusses the questions of biological influence of natural zeolites – clinoptilolite-containing tuffs and peaty-zeolitic and organo-zeolitic fertilizers prepared on their basis, on the qualitative and quantitative composition of soil microorganisms.

It is shown that their influence causes the reproduction of useful microflora, in particular azotobacter. Azotobacter contributes to fixing air nitrogen by transferring it into the so-called "biological" one. The latter is cheaper than technical fertilizer that is applied into the soil as mineral one. Furthermore, far from contaminating the soil, it largely supplements its nitric stock of the soil reserve.

It is established that under the influence of organo-zeolitic fertilizers, the quantity of useful soil microflora increases, being of pulsatory character due to the reproduction and necrosis of microorganisms.

It must be noted that under the influence of zeolites and especially organo-zeolitic fertilizers the intensive vitality of bacteria continues in winter period. *© 2008 Bull. Georg. Natl. Acad. Sci.*

Key words: *natural zeolites, organo-zeolitic fertilizers, soil, microflora..*

Zeolites relate to unique porous bodies that possess simultaneously high adsorptive capacity with well-defined molecular-sieve effect; and ion-exchange features. These attributes differ them from traditional adsorbents such as: alumina, silica gel, activated carbon [1,2].The physio-chemical properties of these adsorbents – ion-exchangers are studied well enough and presented in scientific literature [1-5].

It must be noted that in practice, while developing various technological processes, both natural and synthetic zeolites are used. In different fields of agriculture, natural zeolites of sedimentary origin are mainly used [3,6,7].

On the other hand, such important and unusual abilities of zeolites, as well as their biological activity, have not been the subject of in-depth studies, and scanty scientific literature is represented by individual papers. Conditionally, these studies can be divided into two groups: a) utilization of zeolites in different cation-exchange modifications (Ag+, Cu++, Zn++) as antibacterial agents for the suppression and annihilation of dangerous microorganisms such as *E-coli, S. Serratia aureas, E-faecalis, P-aeroginosa, S-epidermidis, C-albicans, A-calcoaceticus* [8-10]; b) study of the influence of natural zeolites and organic and mineral fertilizers, prepared on their basis, on the microbial landscape of soil for the development of useful microflora in it [11-19].

Today the tendency to move from industrial plant growing to biological, as ecologically safe means, is observed world wide. In this case considerable attention is paid to the use of useful soil microorganisms in high agriculture, with a limited application of mineral fertilizers and toxic chemicals.

Application of zeolites, possessing biological activity, in plant growing fits well the requirements of contemporary biological agriculture [20].

From the second-half of the past century to the present time in a number of countries, zeolitic rock – mainly clinoptilolite-containing tuffs - are added to the soil, in order to increase the yield of various crops [12,21-27].

The works of Italian scientists can be mentioned as an exception. They used natural zeolites of local deposits in plant growing, which represented a mixture of phillipsite and chabazite [28].

In most of these researches, representing the early period, an increase in the yield of various agricultural plants under the influence of zeolites was caused by conditioning (structuring) the soil; improvement of its physico-chemical properties (creating favorable air and water regime close to the plant root system); increased cation-exchange capacity of soil; regular and rational plant nutrition. Only in [19] instructions are given that application of a substrate that contains clinoptilolite, synthetic apatite and dolomite, nitrifying bacteria – increases the test plan grain output 2.5- 6.6 times as compared to the control.

In study [29] it is suggested that the most urgent problem of present-day plant growing is to determine the correlation between the qualitative and quantitative composition of the microbial soil landscape formed under the influence of natural zeolites, and crop yield. In other words, soil microorganisms play a determining role in increasing the fertility of poor and unproductive soils.

In analyzing the results of available studies on the microbial landscape development under the influence of clinoptilolite-containing tuffs the following three directions could be pointed out:

1. Utilization of untreated clinoptilolite-containing tuff (applying a fraction of this rock with 0.5-1.0mm granulation) directly to soil or hothouse soil.

2. Joint utilization of clinoptilolite-containing tuff with material rich in organic substances (peat).

3. Utilization of clinoptilolite-containing tuff and mixtures of organic fertilizers (manure, poultry droppings).

One of the indirect indicators of the biological action of soil microorganisms that are activated by the presence of zeolites in soil or in the substrates of hothouse soil is measuring the intensity of released carbon dioxide. This is related to the rate of decomposition of organic soil parts [13]. The quantity of released carbon dioxide was determined by the chromatographic method [11,15].

Authors [11] estimated that the quantity of released carbon dioxide within twenty-four hours (mg/kg soil) in a mixture consisting of 90% of red soil and 10% of zeolite amounting to 4.2 mg/kg, to the content of 20% zeolite gave 6.46 mg/kg, i.e. 3.2 and 5.2 times higher, respectively, than in pure soil (1.28 mg/kg). Such a sharp increase in the intensity of organic substance decomposition causes considerable humus loss, thereby deteriorating the agronomic properties of the soil. This negative phenomenon can be leveled by two means: by decreasing the doses of zeolites applied in soil or by introducing matter in system slowing process of intense decomposition of organic substances. Peat can be such matter.

Any peat consists of unhumused plant residues, humus and mineral inclusions. Moreover, maintenance of organic compounds in it varies between 85-98% [30]. It is rich in nitrogen in terms of organic compounds, which are stable to microorganisms' decomposition and therefore hardly available for plants. Its biological activity can apparently be activated with the help of clinoptilolite-containing tuffs. That is how in the system of soil-clinoptilolite-peat (80%-10%-10%) the quantity of released carbon dioxide comprised 1.83mg/kg. Whereas in the same system respectively with 60%-20%-20% - 2.37mg/kg i.e. 1.4-1.9 times higher than in the soil. Thus, this system appears to have somewhat decreased intensity of organic substance destruction, but remains at a high level, compared to the control (pure soil).

On the other hand, this contributes to the regular flow of organic substances' destruction processes and to the yield of biogenic elements to plants in an accessible form.

The study [13] serves as confirmation of the fact that in peat decomposition of organic substances takes place under the influence of zeolites. It is also stated that in the case of 25% clinoptilolite-containing tuff application to peat, the intensity of carbon dioxide evolution will be 1.4 times higher than in pure peat.

In another work [31] it is shown that enrichment of hothouse soil by the rejects of technical cotton, in which the content of cellulose comprises 90%, and clinoptilolite in the ratio of 6 kg of technical cotton and 3.6 kg of clinoptilolite-containing tuff, with the introduction to 1 m^2 of ground, increases the intensity of the evolution of carbon dioxide 2.2 times in comparison with what occurs in hothouse soil. This bears out the fact that, under the action of zeolite, there occurs an increase in the activity of the cellulose-decomposing aerobic microorganisms.

The biological activity of soil is caused by the presence in it of microorganisms which take a most active part in the processes proceeding in it. Depending on their qualitative and quantitative composition, they can exert both positive and negative influence on the fertility of soil.

In the case of long use of mineral fertilizers and pesticides in soil, it gradually accumulates toxic substances. Therefore, the quantity of soil microorganisms decreases and in some cases causes the development of undesired microflora, particularly, mold fungi. [11,15] This can be said mainly about acid soils, which are widely represented in Georgia.

In order to prevent these undesirable effects different methods are worked out. Amongst these methods, soil enrichment with natural zeolites is very actual, as this favorably influences the creation of "useful" soil micro landscape [11, 12, 15-18]. In this connection, studies were conducted on the influence of clinoptilolite containing tuff on the formation of microbial association in the soil and to determine the quantization and qualitative composition of microbes in the presence of this mineral soil [11, 15, 16].

The study of microbial landscape was conducted with the help of capillary microscopy [32, 33]. However, for a more detailed study of microbe morphology the method of electron microscopy was used [15]. Microscopic analysis of acid soils of Georgian humid subtropics [11, 15, 34] showed that mold fungi appear to be the focal centre of microflora. Bacterial flora is represented (relatively) somewhat poorly, occasionally with amoebas of small dimensions. By the application of ammonium sulfate to the soil the quantity of mold fungi increases. In the presence of 5% zeolites in the soil both qualitative and quantitative change of microflora is observed: mycolitic bacteria dominate, causing lysis or devouring of mold fungi. At increasing the zeolite quantity to 10-15% in the soil, the microbial landscape becomes even more diverse. The main component of microbial coenosis is bacterial flora, with mycolitic bacteria prevailing. This causes a 2-3 times decrease of the quantity of mold fungi both in red and podzolic soils.

Application of clinoptilolite into the soil results in the emergence of giant amoebas with dimensions of 50-60 microns. This points to an increase in the porosity and improvement of soil structure.

Under the influence of clinoptilolite-containing tuffs in red and podzolic soils, which are weakly populated by actionomyces, their quantity sharply increases. This contributes to the sterilization of soil from undesirable microflora, since it is known that these microorganisms are antibiotics protectors of bacterial microflora.

Such change of the qualitative composition of microorganisms in the soil can be explained by the fact that the introduction of zeolite into soil decreases its acidity. This enhances the development of actinomycete, whereas mold fungi prefer an acid medium.

Especially important is the fact that the introduction of zeolite into the soil positively acts on the growth and reproduction of such useful microorganisms as azotobacter and of the blue-green algae, which are capable of fixing atmospheric nitrogen, transferring it into "biological", thus supplementing the nitric stock for soil and increasing its fertility.

These bacteria are very demanding to the reaction of the medium. They prefer neutral soils, get along poorly with an acid medium and are very moisture-loving. Therefore the enrichment of soil with zeolite creates all conditions for an intensive development of these microorganisms. It is established that introduction of clinoptilolite-containing tuffs into acid soils of the moist subtropics of Georgia increases the quantity of nitrogen fixes by 30-40%.

Positive action of clinoptilolite-containing tuffs on the qualitative composition of microorganisms in soils depends on the type of the latter. Thus, in humus-carbonate soils, which are characterized by a weakly alkaline reaction (pH = 7.2), the content of actinomyces is higher than in podzolic and red soils.

Introduction of clinoptilolite into this type of soil, on the contrary, causes, to a certain extent, quantitative reduction of actinomyces. A similar pattern is observed also in the number of azotobacter, but in practice does not influence the number of mould fungi. Apparently, with certain caution, this can be caused by the insignificant growth of the alkaline reaction of soil from pH=7.2 to pH=7.45.

Joint introduction of peat and clinoptilolite makes soil microflora more diverse: oligotrophic microorganisms appear, in particular Microcyclus and Hyphomicrobium, as well as unknown organisms with uncommon forms and complex cell structure [11].

Along with a qualitative change in the microflora, introduction into the soil of clinoptilolite-containing tuffs contributes to a quantitative change in the microorganisms. The number of microbes in the soil was determined by direct microscopy by the Vinogradsky method [35]. The number of microbes in the soil changes not only seasonally, but also undergoes short-term or, so-called periodic, changes. The latter is connected with the biological features and, in particular, with the alternation of reproduction and mortality of microorganisms.

The study of the daily dynamics of the quantity and biomass of microbes was accomplished in the following variants: soil; soil-peat (9: 1); soil-clinoptilolite (8.5: 1.5) and soil-clinoptilolite-peat (8: 1:1). The duration of observations was 22 days (November 1984). Changes in the quantity and biomass of bacteria are of pulsating nature, which is more pronounced in the systems: clinoptilolite-soil and soil-clinoptilolite-peat than in different variants [36], indicating a more intensive development of microflora.

Calculation of the total mass of bacteria over 22 days of observations totals, according to the variants (in mg/g soil): 2.69; 2.66; 5.32 and 3.88 respectively. Thus, the productivity of bacteria in the system of soil-clinoptilolite increased 1.8 fold and in the system of soil-clinoptilolite-peat 1.4 fold as compared to the soil. A certain positive effect on the number of bacteria in the soil is rendered by plants growing in the systems under consideration [15].

This is probably caused by the fact that for the microorganisms additional sources of organic matter appeared in the soil, which were in the form of the root isolations of plants and cells of root ends constantly dying off. In aggregate, this leads to the optimization of conditions for the development of microorganisms.

As already indicated above, the influence of clinoptilolite-containing tuffs in acid soils created favorable conditions for the nitrogen-fixing bacteria. This in turn must have an effect on the enrichment of soil by “atmospheric” nitrogen.

It is shown [37] that with the application of 10% clinoptilolite-containing tuff to acid soil (pH=4.2) during the vegetative period - 250 days, nitrogen in the quantity of 36. kg/ha is accumulated in the soil, and with 15% - content of clinoptilolite-containing tuff – 58.8 kg/ha.

With the introduction of clinoptilolite together with peat in the soil, the process of nitrogen accumulation is reduced. Thus, in the presence of 10% peat and 10% clinoptilolite in the soil, the quantity of fixed nitrogen equals 29.1 kg/ha, whereas with soil containing 7.5% of peat and 7.5% of clinoptilolite – 47.0 kg/ha. In the control (soil) the accumulation of nitrogen within this period of time was 9.0 kg/ha. Thus, the use of both clinoptilolite and its mixture with peat, enriches the soil by nitrogen 3-6.5 times more than is the case in the control. The interrelation between the number of nitrogen-fixing bacteria and the quantity of nitrogen fixed by soil is confirmed by this experiment.

It is of significant interest in application of the new organo-zeolitic fertilizer in the practice of plant growing. This fertilizer differs significantly from the mineral fertilizers both in the sense of an increase in the harvest and from an ecological point of view.

Back in 1965, studies carried out in Japan showed that application of a mixture of natural zeolite with bird droppings, plant growing is more effective than application of only clinoptilolite-containing tuff [38]. In Georgia similar work was initiated in 1980 which also showed the high effectiveness of using similar fertilizers in vegeculture [39].

However, the mechanism of the positive action of these fertilizers is demonstrated somewhat weakly in the scientific literature. It is assumed and confirmed by experimental data that the effect of positive influence of the system: organo*-zeolite-soil, is caused, in essence, by the creation in the latter of a favorable microbial landscape with a high content of useful microflora [11,15,17,18,40].

Prof. P.J. Leggo uses with respect to this system [18] a very interesting term: “bio-fertilizer”; which in essence reflects the interrelation between “ammoniation” of zeolite and bacterial population in the soil. The correctness of this term is indirectly confirmed by our experiments, executed under laboratory conditions [41].

The experiment was carried out as follows. In the desiccators with the air, nitric and argon media were respectively placed the Petri dishes at proximity with each other, with moistened clinoptilolite-containing tuff (granulating 0.5-1.0 mm) and fresh bird dropping. The experiment lasted 163 days (beginning 09.02.1988 - end 21.06.1988).

Once a month zeolite samples were taken, in which the content of ammonium (using: Nessler’s reagent) and nitrate nitrogen (using the disulfophenol method) was determined. Intensive accumulation of ammonium nitrogen by zeolite was established, being of pulsatory nature and sharply lowered, depending on the environment medium in the sequence: air-nitrogen-argon.

The maximum quantity of accumulated ammonium nitrogen totals respectively 0.45; 0.40; 0.08 g/kg. The process of nitrification begins approximately on the 30th day after the beginning of the experiment and reaches in the air medium 0.7 g of nitrate nitrogen per 1 kg of zeolite. Usually, for the cultivation of different crop cultures in soil, nitrogenous fertilizers at 0.15-0.30 g/kg of soil are introduced [30].

Apparently favorable conditions in this system are created for the development of nitrogen-fixers and other useful microflora. Fresh poultry manure barely contains ammonium nitrogen [30]. The major portion of nitrogen in it is represented in the form of uric acid, which during storage is converted first into urea, and then into car-

*Note: Organic fertilizers are used as organic matter: poultry manure, cattle manure, and pig excrements.

bonate ammonium.

However, manure is the supplier of most varied microorganisms. On the other hand, zeolite, apart from its specific structural feature and alkaline reaction, is characterized by the presence of the chemical composition of such microelements as iron and molybdenum [42], which affects nitrogen accumulation positively [43]. All this contributes to rapid reproduction of nitrogen-fixers in the indicated medium and reduction of molecular nitrogen to ammonium.

In the control: soil; poultry manure; zeolite; accumulation of ammonium nitrogen practically does not occur.

Introduction into the soil of organo-zeolitic fertilizers also has a significant effect on the micropopulation, basically on their quantitative composition. In 1980-1983, in Ukraine, work was conducted under field conditions on soddy-podzolic soil, with the salt extract, the acidity of which amounts to pH=4.0-4.3, with the introduction of clinoptilolite-containing tuff, against the background of NPK – manure changes the quantitative composition of soil microorganisms to a considerable extent [12]. Actually in this case we deal with the system: soil- mineral fertilizer- organic fertilizers – clinoptilolite-containing tuff.

It is shown that in this system, with the introduction of 10 t/ha of clinoptilolite into the soil against the background of NPK-manure in the year of introduction and also during the subsequent years there occurred a stimulating action of zeolite on the quantity of microorganisms. Thus, even three years after the introduction of zeolite into the soil, it contained 1.52 times more bacteria that use nitrogen of organic sources; 1.49 times bacteria using nitrogen of mineral sources; 2.0 times spore ammonifixators; actinomyces- 2.51 times; 1.3 times cellulose decomposing aerobic microorganisms than in the soil without zeolites.

A certain decrease in the quantity of fungi also took place. With an increase in the dose of zeolite up to 20 t/ha, there mainly occurs an increase in the quantity of bacteria that use nitrogen of mineral sources and spore ammonifixators.

Positive influence on the qualitative-quantitative composition of soil microorganisms is experted by organo- zeolitic fertilizers not only to acid but also weak-alkaline soils [14, 44]. The experiment was executed under field conditions on weak-alkaline soils (pH=7.4) in Gardabani district of Eastern Georgia.

According to agrochemical indices the soil of this region relates to meadow, grey-cinnamon, well irrigable. As the organo-zeolitic fertilizer was used the mixture of clinoptilolite-containing tuff from the deposit of Tedzami (Georgia) (granulation 0.5-1.0 mm) and fresh poultry manure, at the ratio of 1:1. After thorough mixing of these components, a properly loose mass was obtained, which was introduced into the soil with the ploughing at the total depth of arable layer.

Beginning of experiment - December 1990; duration - 28 months; end - March 1992. Fertilizers were introduced in November 1990. The diagram of the experiment is the following: the first variant - absolute background (soil without fertilizers); the second variant - organo-zeolitic fertilizer was introduced into the plots at the rate of 20 t/ha; the third variant - plot contained organo-zeolitic fertilizer at the rate of - 40 t/ha and fourth variant - plot contained organo-zeolitic fertilizer taken at the rate of 60 t/ha. The fifth variant also served as control, the plot contained only mineral fertilizers at the rate of - $N_{60}P_{90}K_{45}$ kg/ha. The sixth version - plot contained a mixture of organo- zeolitic and mineral fertilizers at the rate of 20 t/ha and $N_{60}P_{90}K_{45}$ kg/ha. The seventh variant - plot contained a mixture of organo-zeolitic and mineral fertilizers at the rate of 40 t/ha and $N_{60}P_{90}K_{45}$ kg/ha. The eighth variant - plot contained the mixture of organo-zeolitic and mineral fertilizers at the rate of 60 t/ha and $N_{60}P_{90}K_{45}$ kg/ha. Total area of experimental plot - 400 m^2; each separate plot - 40 m^2; replication of experiment was fourfold. The sampling process for the determination of microorganisms was carried out monthly at the depth of 0-20 cm. The total number of microorganisms in the soil was determined as well as qualitative composition in the separate groups (Table 1).

The following was determined: 1.Saprophytic grouping of microflora which participates in the decomposition of organic substances, mainly, humus; 2. Grouping of the spore-forming bacteria whose development is connected with the presence of the processed organic matter in the soil; 3. Fungi capable of accomplishing various processes of the transformation of organic substances; 4. Nitrifying bacteria capable of oxidizing organic substances to nitric acid, the power sources of which are ammonia, hydroxylamine, nitrates – generally encountered in soils; 5. The denitrifying bacteria whose vital activity leads to essential losses of compounds valuable for the plants, mainly nitrogen (their action results in the reduction of oxidized forms of nitrogen to oxides of nitrogen or molecular nitrogen); 6. Nitrogen-fixing microorganisms capable of processing molecular nitrogen of the air, thereby increasing soil fertility; 7. Cellulose decomposing bacteria, aerobic microorganisms and anaerobic mesophilic and thermophilic bacteria, for which manure-containing soil is the most favorable liv-

Table 1

The Influence of Organo-Zeolitic Fertilizers on Quantity and Relation of Separate Groups of Microorganisms in Meadow, Gray-Cinnamon Soil of Gardabani District (Eastern Georgia)

Variants	Total # of Microorganisms (M/O) Thousand (thou)/ 1g of soil	%	Unidentified Bacteria		Saprophytic Group		Spore		Fungi		Nitrifying Bacteria		Denitrifying Bacteria		Nitrogen Fixer		Cellulose decomposing M/O	
			Thou/ 1g soil	% cont. to total # of M/O	Thou/ 1g soil	% cont. to total # of M/O	Thou/ 1g soil	% cont. to total # of M/O	Thou/ 1g soil	% content to total # of M/O	Thou/ 1g soil	% content to total # of M/O	Thou/ 1g soil	% cont. to total # of M/O	Thou/ 1g soil	% cont. to total # of M/O	Thou/ 1g soil	% content to total # of M/O
	0		1		2		3		4		5		6		7		8	
1	194402	100	80395	41.1	112767	57.95	828	0.43	110	0.06	273	0.14	15.2	0.008	12.6	0.006	0.88	0.0005
2	319540	100	139524	43.7	175904	55.0	1092	0.34	182	0.06	2689	0.84	21.8	0.007	50.3	0.016	7.03	0.0022
3	375993	100	171094	45.5	199706	53.1	1068	0.28	138	0.04	3855	1.03	22.2	0.006	104.7	0.028	5.48	0.0015
4	419239	100	193909	46.3	219039	52.1	1372	0.33	144	0.03	4522	1.10	31.0	0.007	195.1	0.047	6.86	0.0016
5	258576	100	106681	41.3	150104	58.0	1128	0.44	100	0.04	519	0.20	17.4	0.007	25.4	0.010	0.99	0.0004
6	349086	100	145098	41.5	199655	57.2	1157	0.33	147	0.04	2886	0.83	23.7	0.007	11.8	0.032	7.17	0.0021
7	427852	100	170026	39.7	252741	59.1	1311	0.31	117	0.03	3454	0.81	22.0	0.005	171.0	0.040	10.28	0.0024
8	494269	100	193802	39.2	293802	59.5	1342	0.27	238	0.05	4718	0.96	27.5	0.006	228.0	0.046	11.37	0.0023

Table 2

Changes in Quantitative Contents of Microorganisms According to Variants Depending on Seasons of the Year. Conditionally, Winter Period of 1990 is Taken for 100% (Comparative Control)

Variants	Winter 1990	Spring 1990	Summer 1990	Autumn 1990	Winter 1991
1	100 %	134.9 %	125.0 %	119.6 %	64.1%
2	100 %	201.3 %	220.8 %	193.7 %	145.4%
3	100 %	239.8 %	237.2 %	197.4 %	134.2%
4	100 %	250.0 %	270.9 %	232.1 %	133.4%
5	100 %	153.4 %	161.0 %	125.6 %	67.2%
6	100 %	237.6 %	234.9 %	177.2 %	167.9%
7	100 %	320.6 %	278.7 %	219.9 %	127.9%
8	100 %	343.0 %	304.0 %	240.3 %	150.2%

ing environment.

Analysis of the obtained data (Table 1) attests to the fact that with an increase in the application of organo-zeolitic fertilizers there also occurs an increase of the total number of microorganisms in the soil both in comparison with the absolute background, 2.2 times and in comparison with the control with the mineral fertilizers, 1.6 times. With the use of a mixture of organo-zeolitic and mineral fertilizers (variant 8), the quantity of microorganisms grows 2.5 and 1.9 times, respectively.

In comparison with the absolute background and the control with mineral fertilizers, the introduction into the soil of organo-zeolitic fertilizers (variant 5), increases the quantity of nitrogen-fixing bacteria 15.0 and of 7.8 times; the quantity of cellulose decomposing microorganisms 7.8 and of 6.9 times; nitrificators 16.6 and 8.7 times, and denitrifixers only 2.0 and 1.8 times, respectively.

With an increase in the quantity of the applied organo-zeolitic fertilizer, the number of nitrificators, cellulose-decomposing bacteria and, especially, nitrogen-fixers desirable for soil fertility, not only facilitates growth but also increases their percentage fraction in the total number of microorganisms. Evidently, the combination of poultry manure and clinoptilolite-containing tuff contributes to the vital activity of the microorganisms pointed out above. A certain increase of alkalinity in the soil caused by the presence in it of clinoptilolite-containing tuff and poultry manure (pH=7.5-8.5) [45] has no negative impact on the vital activity of microflora.

In the same experiment the process of the change of the quantitative composition of soil microorganisms was investigated according to the variants depending on the season in the period from 1990-1991. [14]. The data presented in Table 2 attest to the fact that with the growth of the quantity of organo-zeolitic fertilizers, in particular the mixture of mineral and organo-zeolitic fertilizers, sharply increases the number of microorganisms in the spring-summer period, in comparison with their number in pure soil (without mineral fertilizers). However, introduction of only mineral fertilizers has practically an insignificant effect on the number of microorganisms in the soil.

In the year of introduction (winter period) the effect of organo-zeolitic fertilizers is actually not manifested. However, beginning with the spring, under the action of organo-zeolitic fertilizers, the number of microorganisms in the soil exceeds to a considerable extent their number against the absolute background and in the control with mineral fertilizers.

In our opinion, the very important fact should also be noted that the vitality of microflora against the absolute background and in the control is inhibited (Table 2), while the number of microorganisms exposed to the action of organo-zeolitic fertilizers, far from decreasing in the winter period (1991), even exceeded it against the absolute background of the spring-summer period. This effect occurs largely with the use of a mixture of mineral and organo-zeolitic fertilizers.

The fact that the vital activity of microorganisms at subzero temperatures under the action of organo-zeolitic fertilizers does not stop is confirmed by the experiment (unpublished data), conducted by Prof. B. Ledesert et al in Canada, under the subarctic winter conditions [18].

The presented results of a study are very valuable, since they indicate the possibility of expanding the area of the effective use of organo-zeolitic fertilizers in the subarctic and subantarctic zones of our planet.

Thus, the unique totality of the adsorptive, ion-exchange and bacterial properties of clinoptilolite-containing tuffs and, organo-zeolitic fertilizers – prepared on their basis and allowing to simultaneously condition the soil and to create favorable landscape in it makes them not just competitive to nitric mineral fertilizers but they also exceed the latter according to economic and ecological indices.

მიკრობიოლოგია

ბუნებრივი ცეოლითის — კლინოპტილოლითის შემცველი ტუფის ბიოლოგიური აქტივობა

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სტატიაში განხილულია ბუნებრივი ცეოლითების — კლინოპტილოლითის შემცველი ტუფების და მის საფუძველზე მომზადებული ტორფიან-ცეოლითური და ორგანო-ცეოლითური სასუქების ზემოქმედება ნიადაგის მიკროორგანიზმების თვისებრივ და რაოდენობრივ შემადგენლობაზე.

ნაჩვენებია, რომ მათი მოქმედებით ნიადაგში ადგილი აქვს სასარგებლო მიკროფლორის, კერძოდ, აზოტბაქტერის გამრავლებას, რომელიც ხელს უწყობს ატმოსფერული აზოტის ფიქსაციას. აზოტბაქტერის საშუალებით მიღებული ე.წ. "ბიოლოგიური" აზოტი არ აბინძურებს გარემოს და მნიშვნელოვნად ავსებს ნიადაგში აზოტის ფონდს. იგი ბევრად უფრო იაფია ტექნიკურზე, რომელიც შეაქვთ ნიადაგში მინერალური სასუქის სახით.

დადგენილია, რომ ორგანო-ცეოლითური სასუქების ზემოქმედებით მიმდინარეობს სასარგებლო მიკროფლორის ზრდა, რასაც პულსაციური ხასიათი აქვს და დაკავშირებულია მიკროორგანიზმების გამრავლებასა და კვდომასთან. სტატიაში აგრეთვე აღნიშნულია მნიშვნელოვანი ფაქტი, რომ ცეოლითების, განსაკუთრებით კი ორგანო-ცეოლითური სასუქების, ზემოქმედების შედეგად ნიადაგის მიკროორგანიზმებში ზამთრის პერიოდშიც გრძელდება ინტენსიური ცხოველმოქმედება.

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