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Plant Growing

Use of Natural Zeolites in Plant Growing – Transition to Biological Agriculture

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ABSTRACT. Largely owing to unwise anthropogenic activity large areas of lands good for growing crops were lost in the past century. This was due both to imperfect technico-mechanichal treatment of soil and large scale use of fertilizers and pesticides. Investigations carried out in many countries have shown the feasibility of restoring the fertility of such soils, in particular acid ones, by application of natural zeolites, especially against the background of organic fertilizers. It is shown that under the impact of natural zeolites soil acidity decreases and a definite oxidation-reduction potential is established, this in turn contributes to the creation of a favourable microbial landscape, namely the rise in the soil of gigantic amoebas conducive to the loosening and structurization of the soil, and the number of nitrogen-fixing microorganisms and legume-bacteria that process the air nitrogen into nitrogen fertilizers. All this contributes to obtaining heavy crops - often without using mineral fertilizers. Besides, in contrast to mineral fertilizers, application of zeolites is characterized by a positive effect - effect on the soil for two to three years, i.e. its annual application is not required.

Key words: *biological agriculture, plant-growing, natural zeolites, microbial landscapes.*

In many European countries, Germany in particular, in the second half of the past century a tendency of transition from industrial to biological agriculture was observed [1]. This was caused by the fact that during the past century two billion hectares of fertile lands were irrevocably lost worldwide, i.e. 27% of all lands usable for agricultural purposes, forming the so-called "exhausted", "sick" and "worthless" soils unacceptable for growing crops [2].

The cause of this phenomenon is natural and technical degradation of soil (erosion), in a number of cases due to irrational anthropogenic activity. Thus, in the USA, on plots where maize was cultivated, as a result of regular ploughing, in particular fall ploughing, the average annual rate of erosion is 22.5t/ha, against the regions where ploughing was not carried out at all – 7 t/ha. In the view of scientists, soil erosion is still one of the serious problems in US agriculture [3].

On the other hand, in order to supply the rapidly growing population of our planet, it is necessary to achieve a significant increase of crop yields. In this connection, supporters of industrial agriculture count on increasing the application of mineral fertilizers and pesticides for purposes of achieving heavy yields. Thus, based on 1977 data, in application of mineral fertilizers in cultivating wheat Holland occupies the first place, with 758 kg/ha annual and yield 5.2 t/ha, Japan – 430 kg/ha and 6.2 t/ha, West Germany – 423 kg/ha and 4.5 t/ha, India coming last with 20 kg/ha and 1.4 t/ha [4].

It is noteworthy that the yield of this crop in Western Europe was 5 times less in the 19th century than it is at present [5].

However, the ever increasing application of mineral fertilizers throughout the world has its disadvantages. Firstly, due to imperfect application of these fertilizers, almost 50% of applied fertilizers are not assimilated by plants; they contaminate the environment, and have a negative influence on living organisms. Secondly, there is an opinion that one of the most unpleasant consequences of "dominance" of chemical fertilizers is destruction of humus in soil. It is calculated that throughout the world an average decrease of humus rate is 0.5 – 1.0 %, leading to deterioration of arable layers of earth. Humus – sticky organic substance – gives soil structural state, provides it with an optimal water-air regime. Structureless earth, even with surplus mineral nutrient for plants, will not give a heavy yield [6]. Thirdly – continuous application of nitrogen fertilizers, in particular to light soils, leads to an increase of their acidity, as well as to accumulation of anions of chlorine, fluorine and sulphuric acid [7]. Excessive saturation of the soil with mineral fertilizers can kill or embalm it, as it was [5].

Accumulation of pesticides in the soil also negatively affects the vitality of soil inhabitants. Thus, pestkillers are under the action of these weed-killers, the quantity of dew worms – zoological soil improvers, sharply reduces [8]. Dew worms carry out double functions: loosen and mix the soil, replacing the plough and also enrich it with plant residues.

Frequently, chase for momentary profit may lead to fatal results. Thus, in the USA on some agricultural lands, the total annual cost of application of pesticides amounted to about USD 2.5 billion, and economic effect connected with the decrease of loss in yield was up to USD 10 billion [9]. However, losses connected with the harmful impact of pesticides on the environment and society (human and animal poisoning, contamination of food and agricultural produce, harmful action on natural ecological systems) is not reflected in these calculations. It is said that, in the 70s-80s, according to the amount of DDT in the adipose tissue p.p.m. in the human organism, one's nationality may be identified (Northern American – 12 p.p.m., Western European – 1.2 p.p.m.[10].

Consequently, a very crucial and important world problem arises calling for necessary and urgent actions to render soil healthy; in other words the term "soil fertility" should be replaced with that of "healthy soil". In this connection the advocates of "biological" agriculture propose action to implement measures that may partly solve this problem. Some of these measures are presented in the monograph by the professor Günter Kant [1].

1) Biological loosening and structurization of soil, instead of technico-mechanical, by small soil-inhabiting animals and soil microorganisms;

2) Biological transition of air nitrogen into organic nitrogen-containing compounds through application of leguminous crops and specific soil-inhabiting bacteria and rejection of synthetic products (ammonium, nitrates, urea);

3) Biological control of weeds instead of application of synthetic herbicides;

4) Biological control of stimulants of fungus and bacterial diseases through correct crop rotation, purposeful application of organic fertilizers, giving up treatment of sown areas with chemical bactericides and fungicides.

However, it should be emphasized that biological agriculture does not fully reject the application of mineral fertilizers, as this method considers reasonable, balanced use of agrotechnical, agrochemical and biological methods in complexity with integrated plant protection.

As assumed in biological agriculture (plant-growing) if farm production is not overloaded by technique, mineral fertilizers and pesticides, natural soil fertility does not exhaust; its fertility may even increase.

Analysis of numerous studies carried out throughout the world [11-15], including Georgia [16], shows that demands by biological plant-growing and modern agriculture are actually met through application of natural zeolites of sedimentary origin in cultivating various agricultural crops.

Application of zeolite-containing rocks and organic-zeolite fertilizers, prepared on their basis, facilitate the conditioning of the soil due to rising cationexchange capacity and structure formation due to the development of specific microorganisms within it, decrease of acidity, increasing the capacity to stronger accumulate nutritional elements and gradually transmit them to plants, creating a definite reduction-oxidation regime in the soil, favorable for microbe activity, particularly for increasing the amount of nitrogen-fixing bacteria processing air nitrogen into nitrogenous fertilizer, as well as increasing the quantity of nodule bacteria of cereal-leguminous crops.

All the abovementioned leads to the increase of the yield of crops on the basis of decreased doses of mineral fertilizers, but sometimes without their annual application in the soil with conservation of their positive effect.

To date vast industrial deposits of natural zeolites of sedimentary origin have been brought to light on different continents of the world [17], these minerals have been found in the soil in amount of 5-10%, especially close to zeolite deposits on territories extended about hundred kilometers [18]. They are observed to have a favourable effect on: for example, in Hungary on the territory of Tokai Hills the soil contains a definite amount of mordenite and clinoptilolite; it is here that cultivated grapes are, from which best wines of Europe are produced [19].

Studies that have been carried out in Georgia over the last 30 years on application of natural zeolites in plant growing show that these minerals exert the most effective, positive influence on the chemical, physico-chemical and agrochemical properties of soils that are characterized by low fertility [16].

Studies carried out in the 1980s [20] demonstrated that application of clinoptilolite-containing tuffs in the moist subtropics and acid soils of Western Georgia cause the formation of giant amoebae of the size of 50-60 microns, leading to an increase of soil porosity and looseness, i.e. its structure formation.

It is known that in terms of cation exchange capacity zeolites by an exceed cation exchange capacity of soils [4,21], therefore their application to the soil must contribute to its conditioning. As demonstrated through laboratory experiments, application of phillipsite at the quantity of 20% in the meadow-cinnamonic soil with the cation exchange capacity of 0.39meq/g brings cation exchange capacity up to 0.97 meq/g [22].

Such modification of soil in its turn increases its activity for retention of main nutritional elements of mineral fertilizers, contributes to their more rational use and decreases the hazard of environmental pollution. The retention power in relation to such nutritional elements as NH_4^+ and K^+ is determined by the type of soil as well as by the nature of the zeolite. It is proven through vegetative experiments that grey-brown soil with 20% content of clinoptilolite 1.8 times stronger retains NH_4^+, 2.3 times - K^+, and such soil enriched with phillipsite respectively – 2.2 and 1.8 times stronger than pure soil [23].

The same effect has been observed on loamy soils enriched with clinoptilolite and laumontite-containing rocks, as well as on acid soils containing mordenite and analcime-containing rocks; moreover, most clearly it is manifested in the system of analcime-containing rock-red soil, in which cations of ammonium are retained almost three times more than in pure soil [24]. It is well known that most plants and soil microorganisms develop better in sub-acid and neutral reaction soils (pH 6-7). Excess acid reaction has a negative influence on the forementioned processes [4]. In subtropic zones of Western Georgia acid soils predominate, characterized by low fertility. Application of zeolite-containing rocks in these soils decreases their acidity to various extents, depending on the type of soil, nature of zeolite and its quantity [24,25]. Thus, the greatest rise of pH in soil solution per 1.2 unit may occur at application of phillipsite-containing rocks of about 10% in acid soil (red soil) with 5.1 pH, mordenite-containing rock increases this index by 0.7 unit and analcime-containing rocks – by 0.5 unit.

This has less effective influence on humus-calcareous soils with 6.8 pH. An especially effective influence was demonstrated by application of laumontite-containing rock in strongly acid soils (pH – 4.2) of moist subtropics of Western Georgia where, depending on the application of zeolite quantity, the pH of the soil solution increased from 0.6 to 2.5 units [25]. The results obtained are in full accordance with the data presented in [12].

Reduction-oxidation processes that take place in the soil greatly influence soil fertility. Shift of these processes to the reduction reactions causes a significant rise of activity of soil microorganisms. To estimate the character of reduction-oxidation potential processes in pedology the concept of hydrogen potential rH_2 (Clark index) is applied. If this index is above 27, oxidation processes predominate in the soil. During the creation of a reduction situation in the soil, this index varies within 22-25 and during intensive development of reduction processes its value falls to 20 [26]. Through studies carried out on acid soils of Western Georgia in 1984, both in laboratory and field conditions, it was found that application of clinoptilolite-containig tuffs in the soil shifts this process towards reduction reaction [27], and the index of rH_2 decreases from 21.2 (in pure soil) down to 18.3-18.16, depending on the quantity of clinoptilolite applied in the soil, which also facilitates decomposition of organic substances and intense activity of microorganisms. In [24] data are presented on the investigation of the influence of these three types of zeolite – analcime, mordenite and phillipsite-containing rocks and on the character of reduction-oxidation processes in acid (red, subtropic podzolic) and weakly alkaline (humus-calcareous) soils. It is also estimated that most of these processes most clearly shift towards reduction reaction in the system analcime-containing rock – red soil.

Decreased acidity and predominance of reduction reaction in reduction-oxidation processes in soils influenced by natural zeolites and organo-zeolite fertilizers, prepared on its basis - all these in totality contribute to the development and activation of bacterial population. It is demonstrated that through application of phillipsite-containing rocks and organic-zeolite fertilizers, prepared on its basis, in soils with high acidity rate, 4.5 pH in field conditions during soya cultivation without preliminary treatment with nitragin solution significant increase of number of nodule bacteria by 159% takes place, as compared to the controlling variant of mineral fertilizers [28].

Earlier investigations [20] demonstrated that application of zeolites in acid soils of moist subtropics of Western Georgia cause changes in the qualitative and quantitative composition of soil microflora.

Colonies of mycolytic bacteria appear, causing lysis (devourment) of mold fungi, which are widely spread in the studied soils and 2-3 times decrease their amount in soil. The amount of actinomyces increases three-fold, promoting sterilization of the soil from unfavorable micro flora. An important positive factor is the increase of the amount of nitrogen-fixing bacteria by 30-40%. The change of quantity of bacteria (reproduction and dying out) has pulsating character, taking place with more intensive and higher vibration in the system clinoptilolite-soil than in pure soil. Overall, application of clinoptilolite in the soil promotes an increase of the amount and biomass of bacteria 1.5-2 times, compared to the control variant (of pure soil) with a significant quantity of nitrogen-fixing microorganisms. Application of zeolites against the background of organic fertilizers of poultry manure renders even a higher positive effect as it creates a more favorable mi-

Table 1

Changes in the quantity of microorganisms (%) caused by organozeolitic fertilizers during the seasons (the winter of 1989-1990 is accepted as 100%)

Samples	Winter 1989-1990	Spring 1990	Summer 1990	Autumn 1990	Spring 1990-1991
Control $N_{60}P_{90}K_{45}$ kg/ha	100 %	153.4%	161.0%	125.6%	67.2%
Organozeolitic fertilizers 60 t/ha	100 %	250.0%	270.9%	232.1%	133.4%

Table 2

The influence of zeolite-containing rocks on the basis of mineral and organic fertilizers on the yield of agrcultural crop

№	Agricultural crop	Soil	Years of experiment	Doses of nutritional components	Control for comparison	Increase of yield in % compared to the control variant
1	Maize	Subtropical podzolic (acid)	2001-2003	CLIN (20 t/ha) + p.m. (20 t/ha) PHI (20 t/ha) + p.m. (20 t/ha)	$N_{90}P_{90}K_{90}$ kg/ha $N_{90}P_{90}K_{90}$ kg/ha	≈ 27 (grain) ≈ 40 (grain)
2	Wheat	Gray-brown alkaline	1985-1986	CLIN (45 t/ha) + $N_{120}P_{180}K_{90}$ kg/ha	$N_{120}P_{180}K_{90}$ kg/ha	≈ 11 (grain)
3	Wheat	Brown-typical (weakly alkaline)	2000-2001	LAU (6 t/ha)	$N_{120}P_{180}K_{90}$ kg/ha	≈ 40 (grain)
4	Soyabean	Red (acid)	2003	PHI (20 t/ha) + cattle manure p.m. (20 t/ha)	$N_{60}P_{120}K_{120}$ kg/ha	≈ 54 (grain)
5	Beet	Brown typical (weakly alkaline)	2000-2002	CLIN (15 t/ha) + $N_{60}P_{60}K_{60}$ kg/ha PHI (15 t/ha) + $N_{60}P_{60}K_{60}$ kg/ha	$N_{90}P_{90}K_{120}$ kg/ha $N_{90}P_{90}K_{120}$ kg/ha	≈ 17 ≈ 37
6	Carrot	Gray-brown (weakly alkaline)	1986	CLIN (21 t/ha) + $N_{90}P_{90}K_{120}$ kg/ha	$N_{90}P_{90}K_{120}$ kg/ha	≈ 30
7	Pepper	Gray-brown (weakly alkaline)	1986	CLIN (21 t/ha) + $N_{90}P_{90}K_{120}$ kg/ha	$N_{90}P_{90}K_{120}$ kg/ha	≈ 23
8	Onion	Subtropical podzolic (acid)	2000-2002	CLIN (10 t/ha) + p.m. (10 t/ha) PHI (10 t/ha) + p.m. (10 t/ha)	$N_{60}P_{80}K_{50}$ kg/ha $N_{60}P_{80}K_{50}$ kg/ha	≈ 29 ≈ 12
9	Garlic	Subtropical podzolic (acid)	2000-2002	CLIN (7,5 t/ha) + p.m. (7,5 t/ha) PHI (7,5 t/ha) + p.m. (7,5 t/ha)	$N_{70}P_{80}K_{60}$ kg/ha $N_{70}P_{80}K_{60}$ kg/ha	≈ 20 ≈ 21
10	Cucumber	Gray-brown (weakly alkaline)	2001	NH_4 - ANAL (4 t/ha)	$N_{60}P_{60}K_{30}$ kg/ha	≈ 17
11	Scallop	Gray-brown (weakly alkaline)	2001	NH_4 - ANAL (4 t/ha)	$N_{60}P_{60}K_{30}$ kg/ha	≈ 19
12	Grape	Gray-brown (weakly alkaline)	2002	NH_4 - ANAL (100 g/plant) NH_4 - PHI (100 g/plant) NH_4 - CLIN (100 g/plant)	absolute background of soil without fertilizers	≈ 67 ≈ 80 ≈ 100

Note: Calculations of crop increase in % are carried out by the formula presented in [15].

CLIN- Clinoptilolite-containing tuff
LAU-Laumontite-containing rock
p.m. – Poultry manure
PHI – Phillipsite-containing rock
NH_4- ANAL amonium form of analcime-containing rock
N, P, K – Mineral fertilizer

crobial landscape in soil [29,30]. At the same time, the positive effect occurs even in winter period, in which is not typical of reproduction of microorganisms in usual conditions (Table 1).

However, the main advantage of application of natural zeolites consists in the possibility of partial or absolute renunciation of the use of mineral fertilizers. Application of natural zeolites in the soil without addition or together with organic fertilizers facilitates significant increase of the yield of crops as compared to the influence of only mineral fertilizers (Table 2). In addition, a peculiar feature of these minerals is that they manifest aftereffect, i.e. positively influence the increase of yield after application in the soil, for two to three years, in our case in cultivating maize, beet, onion and garlic (Table 2).

It is obvious from all the foregoing that the main requirements outlined by the supporters of biological agriculture are carried out through using natural zeolites in plant growing. Although, many questions arise in connection with the positive influence on soil, for instance, why on the plots enriched with natural zeolites weeds germinate rarely, why plants growing on soil enriched with zeolites do not usually suffer from diseases? What is the reason that cereal crops, in particular rice, cultivated on soil enriched with natural zeolites are characterized by less lodging? What is the reason that bisexual plants demonstrate a tendency of inclination towards female sexuality after application of natural zeolites in the soil? There are also many questions that remain unanswered; therefore we assume that zeolites, according to the terminology of the German philosopher E. Kant, remain "Thing in Itself" (*Das Ding un Sich*).

მემცენარეობა

ბუნებრივი ცეოლითების გამოყენება მემცენარეობაში – გადახრა ბიოლოგიური მიწათმოქმედებისკენ

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გასულ საუკუნეში მთელ მსოფლიოში ადამიანის უყაირათო მოქმედების გამო დაიკარგა სასოფლო-სამეურნეო კულტურებისათვის ვარგისი მიწების დიდი ტერიტორიები. ამის მიზეზს წარმოადგენს როგორც მათი არასრული ტექნიკურ-მექანიკური დამუშავება, ასევე მინერალური სასუქებისა და პესტიციდების მასშტაბური გამოყენება. მსოფლიოს მრავალ ქვეყანაში ჩატარებული გამოკვლევებით დამტკიცებულია მჟავე ნიადაგის ნაყოფიერების აღდგენის შესაძლებლობა მასში ცეოლითების შეტანით — ეს განსაკუთრებით ეფექტურია ორგანული სასუქების შეტანისას. სტატიაში ნაჩვენებია, რომ ცეოლითების ზემოქმედებით ადგილი აქვს მჟავიანობის შემცირებას, ჟანგვა-აღდგენითი პოტენციალის გარკვეული ნიშნულის მიღწევას, რაც განაპირობებს ნიადაგში განსაკუთრებული მიკრობული პეიზაჟის შექმნას, კერძოდ, გიგანტური ამებების წარმოქმნას, რომლებიც აუმჯობესებენ ნიადაგის სტრუქტურას და ზრდიან მის ფორიანობას.

ამასთან ერთად იზრდება აზოტფიქსატორი მიკროორგანიზმებისა და კოჟრის ბაქტერიების რიცხვი — გაზრდას. ისინი გარდაქმნიან ატმოსფერულ აზოტს აზოტოვან სასუქად. ყოველივე ეს განაპირობებს სასოფლო-სამეურნეო კულტურების მაღალი მოსავლის მიღებას - ზოგ შემთხვევაში მინერალური სასუქების გამოყენების გარეშე. გარდა ამისა, მინერალური სასუქებისაგან განსხვავებით, ნიადაგში შეტანილი ბუნებრივი ცეოლითები ხასიათდებიან ხანგრძლივი მოქმედების უნარით, კერძოდ, მათი მოქმედება გრძელდება 2-3 წელს. შესაბამისად, აუცილებელი არაა ნიადაგში აღნიშნული სასუქის ყოველწლიური შეტანა.

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