Plant Growing

New Substrate of Prolonging Action on the Basis of Natural Zeolite and Brown Coal for Growing Agricultural Crops

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ABSTRACT. On the basis of brown coal and natural zeolite (heulandite-clinoptilolite containing tuff) modified by ammonium and potassium cations a substrate has been developed; the bioproduction of plants grown on this substrate is 2.9 times higher than that grown on soil. This substrate is characterized by long continuous utilization in plant growing. *© 2011 Bull. Georg. Natl. Acad. Sci.*

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Currently, hothouse soils (substrates) consisting of various components (field, forest, soddy, foliar, humous), peat, manure, poultry droppings, straw, buckwheat husk, sawdust, crushed bark of trees, quartz sand, kieselguhr, vermiculite, perlite, mineral wool, gravel, chippings, synthetic exchange resins, slags of metallurgical industry wastes are widely used in the practice of plant growing.

Mostly, the number of components in substrates does not exceed four. Substrates can be conventionally divided into two groups: soil-containing and those that do not contain soil. At present the priority is given to the latter [1].

From the second half of the last century and from the beginning of the present century many researchers have started to introduce the sedimentary natural zeolites (deposits of which widely occur on all continents) into the composition of substrates [2-7]. It has been established that introduction of zeolites into the composition of substrates renders a significant positive influence on the quantitative (productivity) and qualitative indices of the agricultural crop grown on such hothouse soils.

The objective of the present study is to develop an effective substrate not containing soil. This is due to the fact that recently soil is becoming more and more scarc; besides, it is often contaminated with toxicants. In the present study, brown coals of Akhaltsikhe deposits (Georgia) belonging to the humic-sapropelitic group and the class of lean brown coals have been used as an alternative to soil [8]. These coals do not have significant practical utilization, but they contain plenty of organic substances insoluble in water in the form of humic acids and therefore they are inaccessible to plants as nutrient elements. The presence of natural zeolites in the substrate will promote transfer of the above organic substances (contained in brown coals) into water-soluble forms and therefore, an attempt has been made to use them in combination with these minerals.

A number of studies carried out earlier served as the prerequisite to this [9-11]. The data on the development of a lignin-zeolitic substrate, prepared by mixing neutralized lignin (byproduct of sawdust of acid hydrolysis) with clinoptilolite, and enriched with nitrogen-phosphate fertilizers are given in [9]. This substrate has an effective impact on the melioration of polluted soil and on the process of growing ecologically pure crops. It is suggested that Na-K clinoptilolite accelerates the humification process in these substrates and stimulates lignin transformation into free humic acids.

The feasibility of utilizing some low-quality brown coals as fertilizers is shown in one other study [10]. These coals are characterized by a high content of humic acids (25-42 %). By treating these coals with NH_4OH, the authors [10] convert these acids into water-soluble forms, enabling their successful application as fertilizers in the practice of plant growing.

Armenian scientists [11] have developed organo-zeolite fertilizers - clinoptilolite-containing tuffs granulated up to 1mm, impregnated with humic and fulvic acids. These acids are preliminarily extracted from various organic and natural mineral materials (biohumus, peat, bituminous shale, lignite, etc). Greater effectiveness of their application in dehumized soils is established.

In our experiment, unlike the above works, the substrates prepared by mixing heulandite-clinoptilolite-containing tuff modified by ammonium and potassium cations with untreated (raw) brown coals have been investigated.

Material and Methods

Natural zeolites of sedimentary origin, soil and brown coals served as the initial materials for the preparation of substrate.

Natural zeolites – heulandite – clinoptilolite tuffs deposits of Tedzami, Khandaki site (Georgia). The content of the basic mineral in this rock varies within the limits of 70-80 %, calcium prevailing in its cationic composition [12]. Modification of zeolite by cations of ammonium and potassium was carried out by multiple treatment of the initial natural heulandite-clinoptilolite tuff with 0.1N NH_4Cl and KCl water solutions respectively. After each treatment the samples of zeolite were carefully washed in distilled water to remove (substituted) calcium, sodium and potassium cations, extracted from zeolite. Treatment of tuff with water solutions of salts was carried on full till the maximall replacement of the initial exchange cations of zeolite by ammonium and potassium cations. The brown coal deposit of Akhaltsikhe (Georgia), was used as the second component of the substrate.

Soil from the gardening plot of the Institute of Physical and Organic Chemistry in Tbilisi was also selected for the experiment. The type of soil was meadow-cinnamonic, with weakly alkaline reaction of water solution (pH=7.3-7.9). The soil is characterized by low content of humus (1.93 -2.90 %) and may be attributed to heavy loams by its granulometric composition. Capacity of sorption (uptake) of the sum of the bases varies within the limits of 20.91-24.27 mgequiv/100g soil [13]. The experiment was carried out in vegetative pots, in three variants, each in three replications.

In the first variant the soil was used as a substrate. For this purpose slightly dried soil, crushed to granulation <1mm in the amount of 1kg, was loaded into vegetative pots. This variant served as the first control (object of comparison).

In the second variant, the substrate was prepared by mixing the following finely grounded (up to granulation <1mm) components: 25 % zeolite modified by cations of ammonium, 25 % zeolite modified by potassium cations and 50 % soil. 1 kg of this mixture was loaded into vegetative pots. This variant may also be considered as the second control.

The third - main variant is similar to the second one, 50 % of brown coal was used in the substrate instead of soil.

The local variety of spring barley, «new seed», was used as a test plant to study the fertility of the substrate. 50 grains of barley seeds were sown on each substrate (pot). Within 30 days of the sowing, the sprouts together with roots were carefully pulled out of the soil, washed in distilled water, and dried at 75^0C until it reached constant weight. The dry biomass of the plant per pot was determined by weighing, taking into account the whole plant (underground and above-ground parts) as well as the root system alone. In general, five sowings were done consecutively every other month with appropriate processing of the results of each sowing. The beginning of the experiment: March, 2010; duration: five months. The change of the biomass of the grown plants in the process of exploitation of substrate was determined as well. This was carried out by the methodology proposed in [14], i.e. determination of the ratio of the weight of the biomass of the plants in the first sowing to the weight of the biomass of these plants in the subsequent sowings (the second, the third, etc.). In the present paper this ratio is conditionally called the index of exhaustion. The higher this index, the less the fertility (more exhaustion) of the substrate, and vice versa, a decrease in the value of this index testifies to increase of fertility of the substrate.

Results and Discussion

The main results of the experiment are shown in Tables 1, 2, 3. The numerical material of the tabulated data is presented as the averaged values determined from three replications of each variant. It follows from Table 1 that for the first variant, depending on the succession of the sowing, the weight of the dry biomass of the plants decreases; as regards the second and third variants, it rises and is manifested clearer for the third variant, where the substrate consisting of zeolite and brown coal is used.

Table 1.

Change of dry weight of the plant biomass (as a whole) depending on the sequence of sowing and type of substrate

Type of substrate	Dry weight (g/pot) of the plant biomass				
	Sequence of sowing				
	First sowing	Second sowing	Third sowing	Fourth sowing	Fifth sowing
Soil (control)	9.0	8.0	5.0	3.0	2.25
Zeolite-soil	2.0	3.25	11.1	15.75	21.95
Zeolite- brown coal	5.5	12.0	15.0	19.75	29.75

Table 2.

Change of dry weight of the biomass of the plant root system depending on the sequence of sowing and type of substrate

Type of substrate	Dry weight (g/pot) of the plant biomass, sequence of sowing				
	First sowing	Second sowing	Third sowing	Fourth sowing	Fifth sowing
Soil (control)	5.0	5.0	3.0	1.5	1.5
Zeolite-soil	1.25	2.0	9.6	13.75	19.5
Zeolite- brown coal	4.0	10.0	13.0	17.0	26.75

Table 3.

Indices of exhaustion of substrates

Type of substrate	Indices of exhaustion,			
	Sequence of sowing			
	First sowing / the second one	First sowing / the third one	First sowing / the fourth one	First sowing / the fifth one
Soil (control)	1.13	1.80	3.0	4.0
Zeolite-soil	0.64	0.21	0.13	0.09
Zeolite- brown coal	0.60	0.37	0.31	0.11

The total weight of the dry biomass of the plants grown on the soil (the first variant) for five sowings is substantially lower than in the second and third variants and equals 28.25; 54.05; and 82.00 g/pot, respectively. Thus, bioproduction in the second variant is approximately 1.9 times higher; in the third – 2.9 times higher than that in the first variant (control). Bioproduction of the substrate consisting of zeolite and brown coal is 1.5 times higher than on the zeolite-soil substrate. Besides, it has been found that bioproduction of the second variant in the first and second sowings, and in the third variant only in the first sowing is lower than that in the control (soil). The most clear-cut increase of bioproduction in the second and third variants is observed from the third sowing.

In Table 2 the data on the change in the weight of barley root system dry biomass, depending on the succession of the sowing and type of the substrate are given. It has been found that in this case exactly the same regularity of bioproduction change is observed as presented in Table 1.

A comparison of the data presented in Tables 1 and 2 shows that for the same time interval the experiment was carried out, growth and development of the root systems of the plants and not of their above-ground parts take place, i.e. bioproductivity (biomass) of barley increases due to the under-ground parts.

The high bioproductivity of the plants grown on a substrate consisting of zeolite and brown coal in comparison with bioproductivity in the first and the second variants, may probably be explained as follows: in the works, carried out in the 1970s, it was shown that the cations in the composition of zeolites are capable of entering in an ionic exchange reaction not only in water solutions but also in solid state, though the reaction of exchange in this case is slower [15]. Therefore, the following mechanism of ionic exchange in substrate when cations of NH_4 and K^+ of zeolite enter into exchange reactions between humic and fulvic acids, forming appropriate salts soluble in water medium, is possible. In such condition, the formed organic substances can promote humification of the substrate as well as their uptake by plants. On the other hand, high bioproductivity of this substrate, can probably be connected with the formation of a favorable microbic landscape for the growth and development of plants which takes place in zeolite-organic system [16].

In Table 3, indices of exhaustion (relative changes of the bioproductivity of the plants in the first sowing / bioproductivity of plants of the subsequent sowings) of the investigated substrates (three variants) are presented, from which it follows that in the first variant (soil) loss of fertility takes place for each subsequent sowing. Thus, in the fifth sowing these indices are increased approximately four times in comparison with the first sowing.

In substrates with zeolite, this index is significantly decreased, pointing to their high fertility. A very interesting fact is observed, namely a tendency to a decrease of the index of exhaustion on this substrate in the sequence from the first to the fifth sowing, i.e. increase of the fertility of the substrate.

Conclusion

A new substrate has been developed on the basis of ammonium and potassium cation modified heulandite-clinoptilolite-containing tuffs and brown coal. This substrate is characterized by high bioproductivity of the plants grown on it and by the potentiality of long-term, continuous utilization in plant growing.

მემცენარეობა

ბუნებრივი ცეოლითისა და მურა ნახშირის საფუძველზე დამზადებული პროლონგირებული მოქმედების ახალი სუბსტრატის ზემოქმედება სასოფლო-სამეურნეო კულტურების აღმოცენებაზე

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