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Plant Growing

Influence of the Soil-Free Substrate on the Biometric Parameters of Bean and Barley Germination

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ABSTRACT. In the laboratory conditions, influence of the substrate based on brown coal and natural zeolite (clinoptilolite) on the biometric parameters of bean and barley germination has been investigated. In the first version the soil (object of comparison) was used as the standard. In the second version the substrate was produced by mixing 50% of finely-grained (up to grain size < 1 mm) zeolite and 50% of soil. The third main version is similar to the second one, where brown coal (50%) was used instead of soil. The following biometric parameters were determined: germination energy (GE), relative value of germination energy (RVGE), germination (G), relative value of seed germination (RVSG), height of sprout (HS), relative size of height of sprout (RSHS), rate of germination (RG) and intergrowth (IG). As it is seen, introduction of zeolite into the soil has an essential influence on the calculated parameters, raising their values by 2% and higher. These parameters are even higher for the samples containing zeolites and brown coal. Variation of these parameters on the substrate occurs in the sequence: soil (object of comparison) < zeolite-soil < zeolite-brown coal. It was shown that the enrichment of the soil with zeolite in combination with brown coal substantially raises germination and development of the seeded cultures. The present work has preliminary character and the results provide a basis for field experiments, and for more detailed agrochemical research of the examined substrates. *© 2015 Bull. Georg. Natl. Acad. Sci.*

Key words: *natural zeolite, brown coal, barley, bean, biometric parameters.*

A new challenge for the 21st century is food supply for mankind. The area used for agriculture catastrophically decreases under the influence of natural and technogenic degradation (erosion) basically caused by the unreasonable activity of a man.

In this connection, the tendency of creation of substrate with minimal application of soil for the cultivation of agricultural plants, i.e. transition from plant growing to plant production is observed all over the world.

In the practice of plant growing, hothouse soils (substrate) consisting of various components are widely used for cultivation of various agricultural crops. Number of components of the substrate mostly does not exceed four components. Substrates arbitrarily can be divided into two groups: soil contain-

Table 1. The results of determination of germination energies and growth for barley

Result of the analysis	Date of estimation	Number of days from the beginning of sprouting to the date of estimation	Sample A: soil (object of comparison) Seed germination % sample				Average % for 4 samples
			1	2	3	4	
Properly grown seeds in the growth energy for a certain period	20.06.14	3	30	28	32	26	29
Properly grown seeds in the germination energy for a certain period	27.06.14	7	58	56	60	55	57.25
total							Σ86.25

ing and not containing the soil [1]. At present the priority is given to the latter.

From the second half of the last century and the beginning of the present one, many researchers started introduction of sedimentary origin natural zeolites (deposits of which are widely represented on all the continents) into the substrate [2-4].

The works done both in our country and abroad testify that introduction of certain amount of sedimentary natural zeolites into the soil positively affects on germination of various plants. Under the influence of phillipsite (deposits of Italy), germination of such vegetables as spinach and garden radish from seeds increases by 40 and 8.3% [5] and that for sorrel, garden-cress and alfalfa by 9-36% under the influence of clinoptilolite and phillipsite bearing rocks (deposits of Georgia) compared to those grown on the pure soil [6, 7]. Thus, the positive effect of phillipsite bearing rocks is shown in a greater degree than that of the clinoptilolite bearing rocks [7].

Modern agricultural production faces an important and vital problem of raising productivity of all types of agricultural crops without increased doses of mineral fertilizers introduced into the soil.

Natural zeolites play special role in chemical effects on the removal of harmful salts of heavy metals from soil and changing its acidity. The basic purposes of such zeolites are to increase fertility of the soil and ecologically safe production of crops. Application of zeolites leads to purification of soil from pollutants and increase of productivity of agricultural crops by 50-60%.

Some works [8, 9] served as preconditions for the presented research. Data for the development of lignin-zeolite substrate by mixing lignin with clinoptilolite and enriching it in nitrogen and phosphorous containing fertilizers are given in work [10]. This substrate has an effective influence on irrigation of the polluted soil and on the process of cultivation of ecologically safe agricultural crops. The assumption has been made that Na and K containing clinoptilolite accelerates the process of humification and stimulates change of lignin into free humic acids in such substrate.

Possibility of application of low-grade brown coals (deposits of Turkey) as fertilizers is shown in work [11]. These coals are characterized by a high content of humic acids (25-42%). By processing these coals with the solution of NH_4OH, the authors convert the acids into the water-soluble forms allowing their successful application as fertilizers in plant growing. The Armenian scientists [12] developed organic-zeolitic fertilizers - 1mm granulated clinoptilolite bearing tuffs impregnated with humic and fulvic acids. These acids were preliminarily extracted from various organic and natural mineral materials (bio-humus, peat, bituminous slates, or shale oil, brown coal, etc.). High efficiency of their application for the humification of the soil was established.

The objective of the present research is the development of the effective substrate not containing soil. Brown coals (Akhaltsikhe deposits, Georgia) belonging to the humic-sapropelitic group and the class of lean brown coals have been used as an alter-

Table 2. Impact of substrate on seed germination and height of beans

Type of substrate	Soil	Zeolite-soil	Zeolite – brown soil
GE	86	93	99
RVGE	-	0.07	0.06
G	82	96	100
RVSG	-	0.06	0.11
HS	49.0	55.6	59.0
RSHS	-	0.10	0.16
RG	18.1	18.5	19.1
IG	1.2	1.4	1.5

native to the soil [13]. They do not find practical application but have high content of organic components in the form of humic substances. Attempt of their use in combination with natural zeolites was undertaken in assumption that the presence of these minerals in the substrate will assist conversion of the organic substances contained in brown coals into the absorbable forms for plants.

Materials and Methods

Natural zeolites of the sedimentary origin (clinoptilolite), soil and brown coal served as the raw materials for preparation of the substrate.

Natural zeolite – clinoptilolite tuff of Tedzami deposits, Khandaki site (Georgia). The content of the main mineral in this rock varies within the ranges of 70-80%; calcium prevails in the cation content [3].

The meadow-brown soil with alkalescent reaction of its aqueous solution (pH=7.3-7.9) was used in the experiment. The soil is characterized by a low content of humus (from 1.93 up to 2.90%) and it belongs to the heavy loam by the granulometric composition [13].

Table 3. Impact of substrate on seed germination and height of barley

Type of substrate	Soil	Zeolite-soil	Zeolite – brown soil
GE	66	71	82
RVGE	-	0.07	0.19
G	79	81	87
RVSG	-	0.03	0.06
HS	20.9	34.0	36.1
RSHS	-	0.38	0.42
RG	18.9	19.3	19.7
IG	4.7	5.0	5.8

The experiment was carried out in the vegetative vessels, in three versions, each in three replications. For testing the fertility of the substrate, the test plants: barley – "Alaverdi 1" and beans – "Gardabnuli motley" were used [14-16].

In the first version the soil (object of comparison) was used as the standard. In the second version the substrate was produced by mixing of finely-grained (up to grain size < 1 mm) 50% zeolite and 50% of soil. The third main version is similar to the second one, where brown coal (50%) was used instead of soil.

The following biometric parameters have been determined: germination energy (GE), relative value of germination energy (RVGE), germination (G), relative value of seed germination (RVSG), height of sprout (HS), relative size of height of sprout (RSHS), rate of germination (RG) and intergrowth (IG). Germination energy for barley seeds was determined in three days after sowing, and germination on the seventh day, while germination energy for beans was determined in four days after sowing and germination on the eighth day. The results of determination of germination energies and growth of barley seeds for one of the compositions (sample A; soil) are given in Table 1. In a similar way, the data for all the investigated compositions, both for barley and string bean were calculated [17].

According to the State Standard [17], the divergence (%) in the results of analysis of the individual samples by average arithmetic values is $\pm1.4 \div \pm7.0$. In the experiments this divergence was in a range of $\pm2.0 \div \pm4.5$ (%).

Relative germination of seeds of beans and barleys (RGBB) and relative size (height) of bean and barley sprout (RHBB) (Tables 2 and 3) were calculated by the formulas given in [5]:

$$\text{RGBB}\ \% = \frac{NG_{ex} - NG_c}{NG_c} \cdot 100,$$

where, NG_{ex} – number of germination in the experimental version; NG_c – number of germination in the

Fig. 1. Germination of barley on various substrates: A) the soil (control); B) zeolite-soil; C) zeolite-lignite.

Fig. 2. Development of barley root system on the different substrates: A) Soil (control); B) zeolite-soil; C) zeolite-lignite.

Fig. 3. Development of barley root system on the zeolite brown coal substrate.

control version, and

$$\mathrm{RHBB}\ \% = \frac{HG_{ex} - HG_c}{HG_c} \cdot 100,$$

where, HG_{ex} – height of germination in the experimental version; HG_c – height of germination in the control version.

Results and Discussion

The analysis of the data given in Tables 2 and 3 testifies that the introduction of zeolites into the soil positively affects the germination and growth parameters of barley and bean seeds.

As it seen from the tabulated data, introduction of zeolite into the soil has an essential influence on the calculated parameters, raising their values by 2% and higher. These parameters are even higher for the samples containing zeolites and brown coal. Variation of these parameters on the substrate occurs in the sequence: soil (object of comparison) < zeolite-soil < zeolite-brown coal.

The processes of development of the grown cultures on the investigated substrate are presented in Figs. 1, 2 and 3. It should be noted that, basically, growth and development of the plant root systems take place during the experiment rather than the development of the above-ground parts.

From the obtained results it follows, that the enrichment of the soil with zeolite in combination with brown coal substantially raises germination and development of the seeded cultures.

The present work has a preliminary character and the results provide the basis for experiments in the field, as well as for more detailed agrochemical research of the examined substrates.

Conclusion

A new soilless substrate was developed on the basis of clinoptilolite containing tuff and brown coal. These substrates are characterized by higher biometric parameters of the plants grown on them, compared to those grown on the soil.

მემცენარეობა

უნიადაგო სუბსტრატის გავლენა ლობიოსა და ქერის აღმოცენების ბიომეტრულ მაჩვენებლებზე

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მურა ნახშირისა და ბუნებრივი ცეოლითის (კლინოპტილოლიტის) საფუძველზე მომზადებული და ლაბორატორიულ პირობებში შემოწმებულია ახალი ეფექტური სუბსტრატის გავლენა ლობიოსა და ქერის აღმოცენების ბიომეტრულ მაჩვენებლებზე. პირველ ვარიანტში ეტალონის სახით გამოყენებული იყო ნიადაგი (შედარების ობიექტი), მეორე ვარიანტში სუბსტრატი მომზადდა შემდეგი დაქუცმაცებული (მარცვლოვნობა < 1 მმ) კომპონენტებისაგან: 50% ცეოლითი და 50% ნიადაგი. მესამე ძირითადი ვარიანტი მეორე ვარიანტის მსგავსია, მხოლოდ ნიადაგის ნაცვლად გამოყენებული იყო 50% მურა ნახშირი. განსაზღვრული იყო შემდეგი ბიომეტრული მაჩვენებლები: აღმოცენების ენერგია (აე); აღმოცენების ენერგიის ფარდობითი სიდიდე (აეფს); აღმოცენების უნარი (აუ); თესლის აღმოცენების ფარდობითი სიდიდე (თაფს), აგრეთვე ისეთი მახასიათებლები, როგორიცაა: აღმოცენების სიმაღლე (ას), აღმონაცენის სიმაღლის ფარდობითი სიდიდე (ასფს), აღმოცენების სიჩქარე (ას) და თესლთა აღმოცენების ერთობლიობა (თაე). მონაცემთა ანალიზი ამტკიცებს, რომ ნიადაგში ცეოლითის შეტანა შესამჩნევ გავლენას ახდენს გათვლილ მაჩვენებლებზე, კერძოდ მათი მნიშვნელობები 2%-ზე მეტად იზრდება. იმ ნიმუშებში, რომელთა შემადგენლობაში შედის ცეოლითი და მურა ნახშირი, ეს მაჩვენებლები კიდევ უფრო მაღალია. სუბსტრატებზე მათი ცვლილება შემდეგი თანმიმდევრობით მიმდინარეობს: ნიადაგი (შედარების ობიექტი) < ცეოლითი-ნიადაგი < ცეოლითი-მურა ნახშირი. მიღებული შედეგებიდან გამომდინარეობს, რომ ნიადაგის გამდიდრება ცეოლითით მურა ნახშირთან ერთად მნიშვნელოვნად ზრდის მარცვლოვანი კულტურების აღმოცენებასა და განვითარებას. მოცემული სამუშაო მოსინჯვითი ხასიათისაა, ხოლო წარმოდგენილი შედეგები საველე პირობებში გადამოწმებასა და შემოთავაზებული სუბსტრატების დეტალურ აგროქიმიურ კვლევას მოითხოვს.

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