Growth of Seleniferous Wheat with the Use of Natural Zeolite

E. L. ZONKHOEVA[1], V. A. REVENSKIY[1], G. D. CHIMITDORZHIEVA[2], D. B. ANDREEVA[2] and S. S. SANZHANOVA[1]

[1]*Institute of Geology, Siberian Branch of the Russian Academy of Sciences, Ul. Sakhyanovoy 6a, Ulan Ude 670047 (Russia)*

E-mail: elis@geo.buryatia.ru

[2]*Institute of General and Experimental Biology, Siberian Branch of the Russian Academy of Sciences, Ul. Sakhyanovoy 8, Ulan Ude 670047 (Russia)*

E-mail: gal-dorj@biol.bsc.buryatia.ru

(Received November 3, 2006; revised March 14, 2007)

Abstract

Spring wheat with a high content of selenium has been grown using the complex selenium-zeolite mineral fertilizer. The selenium content varies between 4 and 230 μg/L g wheat. It has been found that the use of this fertilizer improves the selenium assimilability by wheat from soil as well as increases the wheat mass by 2–11 %.

INTRODUCTION

Selenium is among 15 vitally needed microelements. Its biological function is specified by the antioxidant and immunomodulating actions.

For every microelement there is a range of safe use, and deviations from this range lead to deficit or excess of microelement. The daily dosage of size 50–200 μg is accepted in the USA [1] as a safe and sufficient level of the daily intake of selenium, and preference is given to seleniferous organic compounds.

As for selenium content of blood serum (the best level is equal to 115–120 μg/L), providing with selenium for 87 % population of Russia may be considered as a moderate one. As to selenium content, Russia may be arbitrarily divided into three groups of regions: with low (60–80 μg/L), moderate (81–110 μg/L), and high (more than 115 μg/L) levels [2]. Low selenium content of blood is observed among inhabitants of Irkutsk, Novgorod, Pskov Regions, whereas inhabitants of Chita Region, Buryatia, Khabarovsk Territory are in critical supply.

Selenium state is corrected by way of rational food, introducing inorganic compounds of selenium into mineral fertilizers (MF), using seleniferous products of mass consumption as well as food supplements.

The selenium content of the wheat can vary with the type of soil. To illustrate, this content makes up 600 μg/kg for the wheat imported from the USA, Canada and Australia, 80–120 μg/kg for domestic one, and may run to 21 400 μg/kg in selenosis regions. The seleniferous wheat is grown in Finland with the use of selenium-containing fertilizers [2].

The selenium migration in biosphere is by trophic circuit, and because of this, the controlling factor in forming selenium state is soil. Selenium is irrelevant to microelements needed for plants as it has no effect on their productivity [3]. It was found that selenium inherent in wheat and other products of plant growing shows the best biological availability, whereas selenium inherent in fish and meat is less available [2]. Selenium inherent in grains of wheat, rye, barley, and oats as well as in seeds of pea, sunflower and flax is only in organic (protein) form [4]. The most essential form of selenium in plants is selenomethionine [2].

It is our opinion that the large-tonnagest foodstuff, namely, wheat may be enriched in selenium through the use of natural zeolite as a microelement carrier. In addition, the use of natural zeolites is appropriate, because they alone contain 11 appropriate microelements and are allowed for the use as food supplements. Further still the selenium introduction into soil in sorbed form makes it possible to control the dose of introduced highly toxic microelement and to prevent its washing by rainfall and carrying away by the wind.

A series of experiments has been carried out to evaluate efficiency of using Se-containing zeolite tuffs as fertilizing supplements for wheat sowing.

EXPERIMENTAL

The clinoptilolite tuff of Kholinskoye deposit (Transbaikalia) with particle diameter 1–2 mm was used in work. The tuff chemical composition investigated in Institute of Geology, SB RAS (Ulan Ude) by standard procedures is the following, mass %: SiO_2 66.8, TiO_2 0.07, Al_2O_3 2.05, Fe_2O_3 1.35, FeO 0.29, MnO 0.06, MgO 0.46, CaO 1.94, Na_2O 1.36, K_2O 3.91, P_2O_5 0.01. The zeolite content of the tuff comprises 70 %, whereas quartz, cristobalite, along with mica, feldspar and volcanic glass are present as admixtures [5].

The sodium selenite solutions were used as sorbates. The selenium content of the sorbents and plant samples was determined by X-ray fluorescent method with the use of VRA-30 device, whereas the solution analysis was performed by the iodometric method [6].

The selenium-containing zeolite tuffs were prepared through saturating natural clinoptilolite tuffs of Kholinskoye deposit with selenium from sodium selenite solution on condition that masses of tuff and solution were in the ratio of 1 : 10. The selenium needed content of the rock [7] was received by using data for the isotherm of selenium (IV) ion sorption measured at room temperature by the method of fixed masses, together with process kinetics studied previously in our works [8, 9]. The obtained preparation was mixed with MF and tested in vegetation experiments with spring wheat of Selenga sort. The mixed selenium–zeolite complex fertilizer was introduced by 50 g in vessels with soil (by 6 kg), and 30 grains were sown in every vessel. But 16 plants were retained in every vessel in tillering phase. An account of the surface mass has been kept in phase of the complete ripeness of grains of main ear stems. The influence of selenium-zeolite proportions on the spring wheat productivity has been studied. Each specific experiment was repeated three times.

RESULTS AND DISCUSSION

The sorption isotherm of selenium ions from solutions of sodium selenite by zeolite tuffs (Fig. 1) has an initial concave section. From this it follows that the adsorbate molecules interact with each other more actively than with a sorbent. The behaviour of the curve at high concentrations points to proceeding polymolecular adsorption [10]. Isotherms of this type testify that the interaction of an adsorbate with a sorbent is of a physical character, and molecules of this adsorbate are arranged on this sorbent surface in the form of chains or clusters.

Insight into the nature of interactions in the zeolite-containing tuff–sodium selenite system and process kinetics [7–9] has allowed a prediction of selenium migration character in the complex fertilizer–soil–plant system.

The results of using selenium-containing zeolite tuffs mixed with MF in vegetation experiment with spring wheat are tabulated in Table 1. Sodium selenite mixed with MF was used as a reference preparation.

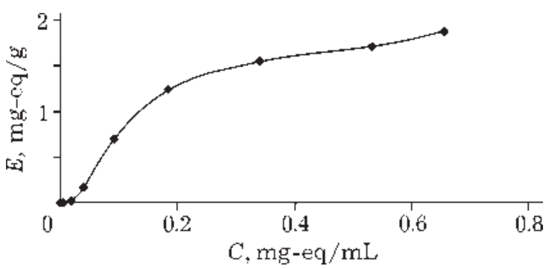

Fig. 1. Sorption isotherm of selenium ions (IV) on natural clinoptilolite tuffs. E is selenium sorption, mg-eq/g; C is equilibrium selenium concentration in solution, mg-eq/mL.

TABLE 1

Effect of selenium-containing zeolite tuffs on selenium accumulation by wheat

Exp. No.	Variant	Overhead mass, g/vessel	Se content, mg/g in overhead mass	Se content, mg/g in grains
1	Control	4.21	<0.003	<0.003
2	$N_{2.9}P_{2.3}K_{2.0}$	27.74	<0.003	<0.003
3	Background + z (zeolite) 10 g/vessel	26.59	<0.003	<0.003
4	Background + z 30 g/vessel	25.18	<0.003	<0.003
5	Background + z 50 g/vessel	24.84	<0.003	<0.003
6	Background + Se 0.5 mg/kg	30.10	<0.003	<0.003
7	Background + Se 0.5mg/kg + z 10 g/vessel	22.75	<0.003	0.004
8	Background + Se 0.5 mg/kg + z 30 g/vessel	21.16	<0.003	0.006
9	Background + Se 0.5 mg/kg + z 50 g/vessel	18.65	<0.003	0.010
10	Background + Se 2.5 mg/kg	26.57	0.012	0.040
11	Background + Se 2.5 mg/kg + z 10 g/vessel	23.70	0.017	0.051
12	Background + Se 2.5 mg/kg + z 30 g/vessel	22.38	0.014	0.045
13	Background + Se 2.5 mg/kg + z 50 g/vessel	22.87	0.013	0.051
14	Background + Se 5.0 mg/kg	20.85	0.032	0.100
15	Background + Se 5.0 mg/kg + z 10 g/vessel	19.20	0.044	0.140
16	Background + Se 5.0 mg/kg + z 30 g/vessel	19.90	0.046	0.120
17	Background + Se 5.0 mg/kg + z 50 g/vessel	20.23	0.056	0.096
18	Background + Se 10.0 mg/kg	21.76	0.130	0.230
19	Background + Se 10.0 mg/kg + z 10 g/vessel	24.75	0.091	0.100
20	Background +Se 10.0 mg/kg + z 30 g/vessel	27.83	0.110	0.210
21	Se Background +10.0 mg/kg + z 50 g/vessel	22.29	0.089	0.190
	$LMD_{0.95}$	0.74	–	–

Note. $LMD_{0.95}$ is least mean difference for a confidence probability 0.95.

The individual introduction of zeolite tuff (exp. Nos. 3–5) or selenium (exp. Nos. 10, 14, 18) on the background of MF tends to decrease an overhead mass of wheat. In the former case a sorption of soil nutritive materials by sorbent takes place. The joint introduction of zeolite tuff and selenium also does not increase an overhead mass of wheat expect for runs 19 and 20. When selenium is introduced in the dose of 0.5 mg/kg, individually and in a sorbed form, it is not detected in the overhead mass, but it is present in grains. The degree of selenium accumulation by the overground mass using its sorbed form in doses of 2.5 and 5 mg/kg is superior to the dose of 10 mg/kg.

In a similar manner, when employing sodium selenite, grains are enriched with selenium to a lesser degree than when introducing a sorbed form. Increasing the sorbed selenium dose to 0.5–5 mg/kg leads to a rise in its content in grains, which is not observed for the dose equal to 10 mg/kg.

When using this know-how, the selenium content of the grains can be from 4 to 230 μg/g. According to our experiments of past years [7], the use of the sorbed form of selenium makes it possible to obtain, without action on the productivity, the more coarse-grained wheat: mass of 1000 grains is 2–11 % higher in comparison with a background (NPK). Wheat of high selenium content can be used for correction of selenium deficit in usual wheat by mixing them as well as can be used as a food supplement. The described sorption technology is also applicable for obtaining the other seleniferous products of plant growing.

CONCLUSION

The obtained results have shown that the use of selenium-containing zeolite tuffs makes it possible to grow wheat with a given microelement content. Doing so will give Russian inhabitants the chance to reduce the dependence of a selenium status on using imported wheat.

REFERENCES

1 National Research Council Recommended Dietary Allowances, 9th Ed., Nat. Acad. Press, 1980.
2 V. A. Tutelyan, V. A. Knyazhev, S. A. Khotimchenko *et al.*, Selen v organizme cheloveka: matabolizm, antioksidantnye svoystva, rol' v kartsenogeneze, Izd-vo RAMS, Moscow, 2002.
3 S. P. Torshin, Vliyaniye estestvennykh i antropogennykh faktorov na formirovaniye mikroelementnogo sostava produktsii rastenievodstva (Author's Abstract of Doctoral Dissertation of Biology), Moscow, 1998.
4 J. W. Hamilton, O. A. Beath, *Agron. J.*, 55, 6 (1963) 528.
5 I. V. Gordienko, L. G. Zhamoytsina, in: Mestorozhdeniya Zabaykal'ya, in N. P. Laverov (Ed.), Geoinformmark, Moscow, vol. 1, book II, pp. 218–225.
6 G. Sharlo, Methods of Analytical Chemistry. Quantitative Analysis of Inorganic Compounds [in Russian], Khimiya, Moscow, 1969, p. 982.
7 Pat. 2283821 RF, 2006.
8 E. L. Zonkhoeva, S. S. Sanzhanova, *Ekol. Khim.*, 11, 4 (2002) 264.
9 E. L. Zonkhoeva, S. S. Sanzhanova, *Zh. Fiz. Khim.*, 78, 12 (2004) 2228.
10 G. D. Parfit, C. H. Rochester (Eds.), Adsorption from Solution at the Solid/Liquid Interface, Academic Press: London, 1983.