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Role of Silicon and High Siliceous Materials in Growing Organic Crop Produce.

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ABSTRACT

As a result of research it has been established that high siliceous materials both of natural origin (diatomite), and artificially synthesized (Mival-Agro) are an effective means of protecting young crops, of increasing productivity and obtaining organic produce owing to silicon which is contained in them. For example, the use of diatomite in the system of fertilizing tomatoes in a dose of 5 t/hectare almost completely or fully protected plants from blossom-end rot. At the same time under conditions of commercial production the yielding capacity has increased by 3,5 t/hectare (44%), an intake of heavy metals in produce considerably decreased (in lead up to 6,5 times). A similar tendency was observed in cultivation of other crops (spring wheat, barley, sugar beet).

Keywords: high siliceous rocks, diatomite, crops, ecologically safe produce.

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INTRODUCTION

To grow organic produce in the plant growing branch is one of the major problems in the whole world including Russia. In its solution the application of natural sorbents – the minerals and rocks possessing high sorption properties in crop cultivation technologies becomes its priority direction. Among them, from the point of view of a possibility of use in agricultural industry, opal-cristobalite rocks (silica clay, bergmeals, diatomites) which are provided mainly by amorphous dioxide of silicon (more than 50%) are of great interest.

Silicon, being the major nutrient, creates the immune system of plants, increasing their natural resistance to any stresses caused by both biogenous (insects, pests, diseases), and abiogenous (low and high temperature, contamination by toxic substances, etc.) factors [1.2]. The relationship between silicon and resistance of plants to heavy metals has been studied widely. Monosilicon acid is known to be able to form almost insoluble silicates with heavy metals that dramatically reduces their mobility and intake in a plant [3].

It should be noted that the role of silicon in the system "soil – plant" is very considerable and stipulates the need of in-depth studies not only of a functional role of silicon as the element promoting an increase of resistance in a vegetable organism to various external factors, but first of all, optimization of silicon plant nutrition. Despite the fact that silicon dioxide is the most widespread substance of the lithosphere, deficiency of available silicon [3, 4] is possible due to its uptake by harvested crops on any soils.

With yielding capacity of grain crops within 2,0 – 6,0 t/hectare the balance of silicon in agrocenoses is always negative and deficient in 6 - 20 kg/hectare [5].

All the above mentioned assumes a possibility of using silicon compounds, both to increase productivity, and to obtain organic crop produce. This is what our research is devoted to.

Objects, conditions and methods of research:

Objects of research were: crops: diatomite (high-siliceous rocks) crushed to a powdered condition with content of silicon dioxide of 85,2% (42% in amorphous condition). Besides, diatomite comprises 1,06% of K2O, 0,21% of SO3, 0,05% of P2O5 and other elements important from the point of view of plant nutrients; Mival-Agro – a siliceous growth regulator possessing a wide range of biological effect, adaptogenic and antioxidant properties. From the point of view of environmental protection both diatomite, and Mival-Agro are ecologically safe as they do not contain polluting substances (including heavy metals). Moreover, owing to the features diatomite is capable of fixing and effectively neutralizing the most harmful toxicants.

Studying the efficiency of siliceous materials in growing organic crops was carried out on the experimental field of FSEI HE Ulyanovsk State Agricultural Academy during 2000 - 2013. The soil of the experimental field – leached chernozem, medium textured with average humus content, average clay loam with the reaction of soil solution close to neutral, with average and high availability of compounds of phosphorus and potassium.

Field and laboratory experimental studies were conducted according to methodical requirements and state standard specifications. Experimental designs have been provided in the course of discussion of research results. The experiment replication – quadruple, with randomized placement of plots (the accounting area – 20 sq.m), analytical replication – triple.

Research results

The first field experiments to study the efficiency of diatomite in the fertilizer system were conducted by us in 2000 - 2004 with vegetable crops both in small plot experiments and production trials. Results showed an outstanding performance of diatomite as a fertilizer, including protection of plants: productivity of cucumbers increased by 20%, beet by 13%, carrots by 14%, tomatoes by 13%. So, in cultivation of tomatoes the application of diatomite as silicon fertilizer (5 t/hectare) considerably or completely protected plants from blossom-end rot (Bacterium Sycopersici Burgn) and sharply reduced terms of the beginning of fructification and onset of commodity ripeness of fruits (by 10 – 14 days). Similar results were obtained production trials (the area of a plot 5 hectares): plants on the experimental option were practically not affected. The decrease in disease incidence of tomatoes when applying diatomite in the soil was nearly 80%, their yielding capacity at the same time increased by 3,5 t/hectare (44%).

The influence mechanism of silicon on the immune system can be multi-sided. Earlier it was believed that protective properties of silicon which is contained in a plant are explained by the fact that it promotes the strengthening of epidermis walls which become a hard barrier for fungi, insects and other pests [6].

However modern researchers, without rejecting this hypothesis, point to the existence of some other mechanisms of protecting plants by silicon. So, it is supposed that silicon plays an essential role in an increase of plants' ability to resist an infection due to stimulation of natural protective reactions [7, 8]. V. V. Matychenkov [2] considers that active forms of silicon in a plant facilitate fast and directed synthesis of specific molecules in a plant cell which help it to overcome or adapt to a stress.

Results of the studies have shown that diatomite is a unique means at the same time not only of increasing yielding capacity, but also obtaining organic produce (table 1)

Table 1: Influence of diatomite on the content of heavy metals in produce (on natural substance, mg/kg)

Element	Tomatoes (2000 – 2004)		Spring wheat (2003 – 2005)		Sugar beet (2007 – 2009)	
	control	diatomite 5 t/ha	control	diatomite 3 t/ha	control	diatomite 3 t/ha
Zn	15,3	14,4	8,7	7,7	7,2	6,7
Cu	3,3	2,2	2,6	2,1	3,8	3,1
Pb	0,59	0,09	0,18	0,09	0,07	0,06
Cd	0,18	0,12	0,03	0,02	0,05	0,03
Ni	1,15	1,00	0,45	0,40	0,20	0,17

As it is seen from the provided data, the accumulation of toxic elements decreased very significantly in the produce on separate elements when using diatomite in the cultivation technology of crops (in particular, on lead to 6,5 times). Similar results have been received when using diatomaceous powder in the cultivation technology of barley in much smaller quantities – applying into rows in a dose of 40 kg/hectare – and dusting the seeds with the siliceous growth regulator Mival-Agro before sowing crops (table 2)

Table 2: Influence of diatomite and Mival-Agro on the content of heavy metals in barley grain, mg/kg (2012-13)

Variant	Yielding capacity t/ha	Elements				
		Zn	Cu	Pb	Cd	Ni
Control	2,08	22,5	3,9	0,95	0,12	1,2
Diatomite 40 kg/ha (in rows)	2,19	14,0	3,2	0,50	0,08	0,8
Mival-Agro (seed treatment)	2,47	14,5	3,6	0,90	0,12	1,2
MPC		50,0	30,0	5,0	0,30	1,0
$LSD_{0,5}$	0,11	0,80	0,30	0,04	0,01	0,03

It should be noted that the studied produce has been grown far from the sources of technogenic pollution on the soil where the level of the hazardous substance content did not exceed its maximum permissible concentration. On more contaminated soil the effect of diatomite as a sorbent can be much higher as the maximum absorbing capability of sorbents is shown in case of their excessive quantity. In particular, monosilicon acid can form almost insoluble silicates with heavy metals:

$2Zn^{2+}+SiO_4^{4-}=Zn_2SiO_4\downarrow$

$2Mn^{2+}+SiO_4^{4-}=MnSiO_4\downarrow$

$2Pb^{2+}+H_4SiO_4^{4-}=PbSiO_4\downarrow+4H^+$

$Mn^{2+}+SiO_4^{4-}+2H^+= Mn_2SiO_4\downarrow+H_2O$ [9]

The interaction pattern of monosilicon acid with heavy metals depends on its initial and final concentration in the system [2, 10]. In case of a substantial increase of the monosilicon acid concentration in the soil or a solution there is a formation of almost insoluble silicates of metals that sharply reduces their mobility. The amount of this concentration is determined by many factors: particle size distribution, reaction of the environment, content of organic substance, oxidation-reduction conditions etc. Therefore, it is possible to guide the behavioral pattern of heavy metals in the system “soil - a plant” by a change of the monosilicon acid content concentration in the soil solution. In our case by means of applying diatomite which, apart from the big existing sorbing surface is a supplier of monosilicon acid in the soil solution.

Positive experience of applying natural sorbents in crop cultivation technologies can be used in rehabilitation of agricultural lands subject to local contamination, including, for example, with radionuclides owing to the Chernobyl accident.

CONCLUSION

Thus, the conducted studies have shown that high siliceous materials both of natural origin (diatomite), and artificially synthesized (Mival-Agro) are an effective means of protecting young crops, of increasing productivity and obtaining organic agricultural products, owing to available silicon which is contained in them.

REFERENCES

[1] Voronkov M. G. Silicon and life / M. G. Voronkov, G. I. Zelchan, E.L. Lukevich / – Riga: Zinatne – 1978. – 587 p.

[2] Matychenkov V. V. Role of mobile silicon compounds in plants and the system “soil – a plant”; abstract of the thesis of doctor of Biology / Matychenkov Vladimir Viktorovich. – M.: Pushchin – 2008. – 34 p.

[3] Matychenkov V. V. Influence of silicon fertilizers on plants and soil / V. V. Matychenkov, E.A. Bocharnikova, Ya. M. Ammosova//Agrochemistry. – 2002. – No. 2. – pp. 86 – 93

[4] Kulikova, A.K. Silicon and high siliceous rocks in the system of fertilization of crops. / A. K. Kulikova/– Ulyanovsk. – 2013. – 176 p.

[5] Golovanov, D. L. Silicon – an irreplaceable trace element of natural and cultural cereals. / D. L. Golovanov / Fertilizers and chemical ameliorants in agroecosystems. / – M.: MSU publishing house. – 1998. – pp. 247 – 250

[6] Yoshida, S. The physiology of silicon in rice/S. Yoshida//Food Fert. tech. Cent. Tech. Bull. Taipei. Taiwan. – 1975/– No. 4. – pp. 8 – 12

[7] Fawe A. Silicon-mediated accumulation of flavinoid phytoalexins in cucumber/A. Fawe, M. Abou-Zaid, J. Menzies, R. Belanger//Phytopatology. – 1998. – No. 88.

[8] Wang X. Effects of exogenous silicon on seed germination and antioxidant enzyme activities of Monordiacharantia under salt stress/X. Wang, C. Ou-yang, Z. Fan Z.//Journal of Animal & Plant Sciences. – 2010. – No. 6. – pp. 700 – 708

[9] Lindsay W. L. Chemical Equilibria in Soil. N. Y. John Willey & Sons-1979. – 449 p.

[10] Matychenkov I.V. Change of mobile phosphates content of the soil when applying active forms of silicon / I. V. Matychenkov, E. P. Pakhnenko//the Bulletin of the Ulyanovsk State Agricultural Academy. – 2013. – No. 3 (23). – pp. 24 – 28.