

Influence of improved (nano) systems on cultivated corn growth, development and yield

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*Dedicated to the blessed memory of
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ABSTRACT

Using physiologically active, complex, polyfunctional, multicomponent (nano) systems – (nano) chips in the pre-sowing soya treatment (nano) technology allows precise seeding; enhancing field seed germination; reducing plant morbidity rate considerably or even deleting disease incidents; increasing plant adaptability to unfavorable environmental conditions; expanding crop yield; improving products quality by not using toxic chemical means of plant protection; intensifying competitive ability of agricultural products as well as assuring environmental safety in crop cultivation regions.

Keywords: Nanotechnologies; Agricultural; Seeds; Soya; Biopesticides; Immunomodulators; Elicitors; Fungicide; Nanochips

1. INTRODUCTION

One of the modern technologies for development of efficient polyfunctional systems for pre-sowing seed treatment is a technology based on creating (nano) chips coating of the seed surface. The developed (nano) chips consist of porous matrixes, filled with physiologically active, environmentally sound compounds of wide action spectrum «green chemistry», most of which are biopesticides – non-toxic plant protection means, developed from natural raw material resources.

While conducting our research works, we use modified natural materials vermiculite and amino-, oligo - and polysaccharide derivatives as the carriers. These materials are elicitors which induce seed «defence mechanisms» of the entire organism. In 2010 for the first time a concept has been introduced that oligochitosan (as one of the components of the (nano) chips examined) is a vaccine for plants, acting the same way as vaccination influences humans and animals.

As the carriers of (nano) chips we use the local raw material – vermiculite [1].

One of the major and most valuable vermiculite features is that when a range of modification technologies is applied, vermiculite is capable of expanding 100-300 times its original size and even more, it can also considerably increase its absorbing capacity.

This is due to the fact that as a result of modification, the molecular water within the scales and voids of vermiculite turn into vapour under which pressure the mica layers move apart always in the same direction, perpendicular to their cleavage.

This modification facilitates vermiculite expansion by creating very fine (nano) hollows filled with the air remaining between the layers of mica, which gives the mineral various valuable features, a very high absorbing capacity, in particular. All these features determine the considerable potentials of its application as a multipurpose raw material.

Vermiculite has been extensively used in various industry branches for more than 80 years [2]. Vermiculite concentrate is being produced in different parts of the world. Its world market price reaches 300 dollars for a ton, vermiculite is in demand in many highly developed countries. Vermiculite world output has already exceed > 500 000 tons (Fig. 1).

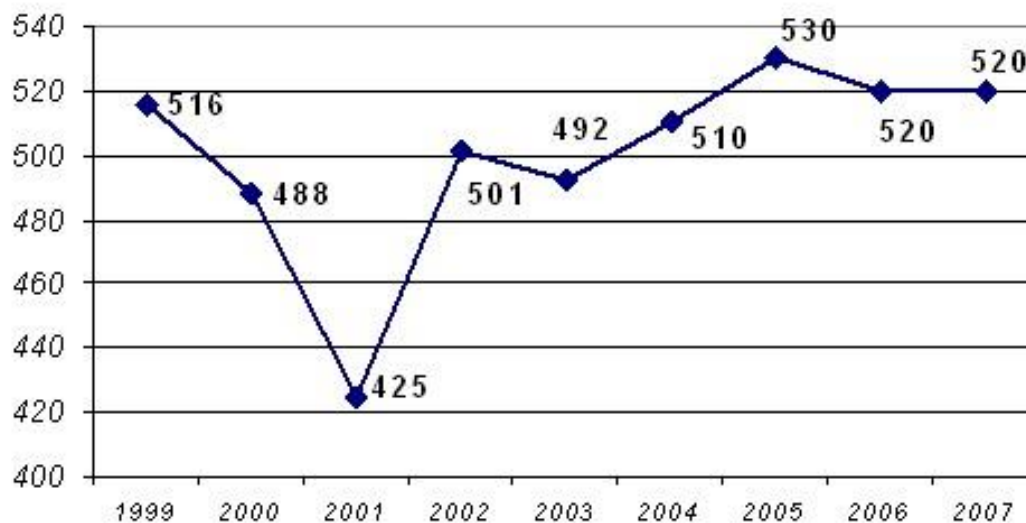


Fig. 1. Vermiculite production in the world in 1999 to 2007, thousand t.

USA, Republic of South Africa, China, Japan, Australia were the leading manufacturers of vermiculite (Fig. 2). In Russia there are also many industrially important vermiculite deposits.

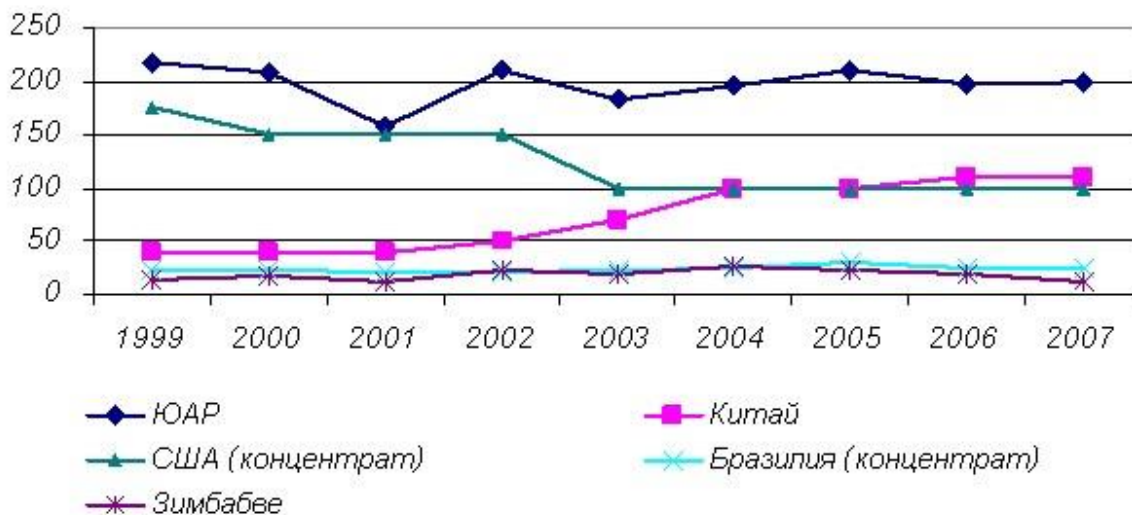


Fig. 2. Vermiculite production on the countries, thousand t.

As the analysis of modern research information sources has shown, 55 % of world vermiculite resources are applied in the sphere of agriculture. In this sphere vermiculite is used for various purposes (Fig. 3).

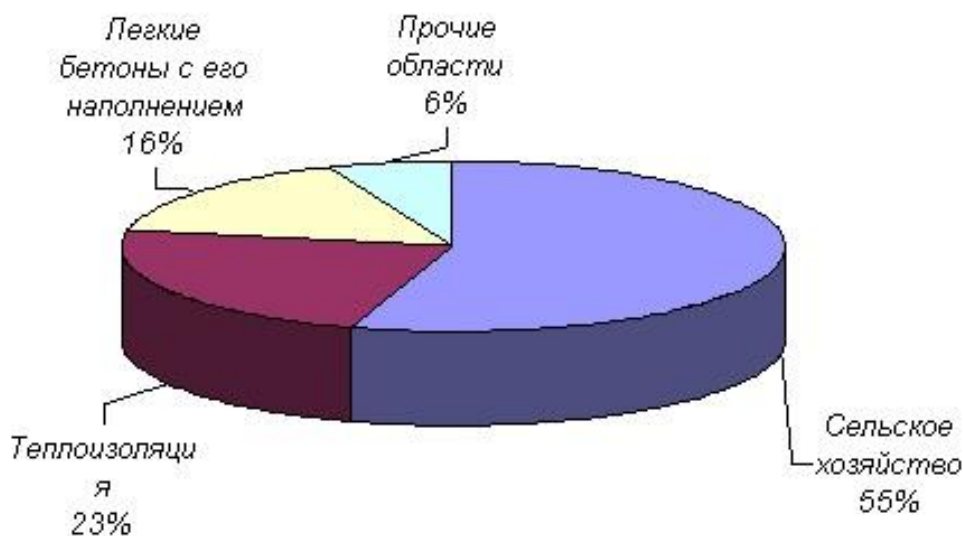


Fig. 3. The global structure of use of vermiculite.

Vermiculite slows down permanent soil salinization process, retains soil moisture and decreases root rot disease. At the same time this natural mineral is used as a source of and also a carrier of plant nutrition microelements for it contains silicon, magnesium, copper, calcium and so on. Thus, this mineral increases yield of various cultures by 12-17 %, decreases the amount of soil ecotoxins; it prolongates the period of exchangeable peaty soil usage; it is the medium for an extended vegetables, fruits and flower bulbs storage. Prepared in accordance

with a specific technology vermiculite has a high moisture capacity and can be used as a soil «conditioner», due to its ability to retain not only water, but also air. It improves the soil structure and controls water-air and thermal conditions, which allows of its wide usage within agricultural cultivation technologies [3-5].

Vermiculite's ability to absorb and retain liquids up to 400 % of its size permits using it together with various organic fertilizers (peat, biohumus, manure and so on). Vermiculite «peat» is frequently used in gardening. Sterility and inactivity are also its advantages. On adding 25-75 % of vermiculite peat mass maintains almost a stable moisture rate even in drought conditions. All these vermiculite features permit to use it on open grounds to prevent moisture evaporation from soil surface and for maintaining soil pH level. The same vermiculite characteristics allow of its wide application as the carriers of phosphoric - potash, nitrogen and other fertilizers. Having an ability to retain fertilizers, porous vermiculite granules also provide their activity prolongation and create more favorable conditions for strengthening the root system of a cultivar.

It is also known that vermiculite can be as well used as a carrier for insecticides, herbicides and so on. "Vermiculitoponics" has also come into an extensive use in various countries. Vermiculite is considered to be a perfect medium for plant growing due to 10-15 times reduction of plant nutrients expenditure, easy treatment process, purity, sterility, its reutilization ability and yield increase (up to 30 times) of various vegetable cultures (tomatoes, cucumbers, potatoes, onions, lettuce and etc.), of legumes and other cultures. The efficiency of "Vermiculitoponics" is high for the fact that modified vermiculite is an active biogenic stimulator of crop yields.

Modified vermiculite is as well used for pelleting small-seeded cultivated plants. Pelleting is an efficient method for sowing seed quality improvement, which consists of creating an artificial nutrient capsule around each seed. Vermiculite is a part of that composition forming a dense capsule around the seed. In practice it has been noted that using vermiculite within the structure of pelleting systems allows of small seed sowing method improvement, germinating capacity increase, cultivation labour inputs reduction and yield increase. Vermiculite mastic is widely used for concrete silo pits protection against mould. Vermiculite is also applied as the medium for storage of fruits, vegetables, plant tubers, bulbs, cuttings and etc. in storehouses and during long distance transportation. For example, vermiculite facilitates 100 % preservation of potato tubers, when in normal storage conditions the losses usually make up 13-15 %. Storing in vermiculite has several advantages: smaller storage areas, greater moisture and temperature stability.

Vermiculite as a biostable, sterile and effective moisture-retaining material is also used as the medium for storing vegetables and fruits in permanent storehouses, in clamps and trenches instead of sand and soil, which form a substrate for microorganism development (rot and mould) and are usually infested with simplicidentates and pests.

Assimilable forms of magnesium, potassium, iron and calcium that are present in vermiculite enrich the soil with micronutrients. Plants develop better in such soil, fruit 1-2 weeks earlier and are resistant to diseases. Yield increases by 20-30 % due to soil water-air conditions improvement and plant nutrition optimization. Ornamental and medicinal plant growing in open or covered soil or in room conditions is a special vermiculite field of application. As an ornamental mulch vermiculite (fine and small or large) is put on the soil surface. Vermiculite is also applied for compost production, where litter manure, poultry dung, peat, ground straw and stems of various cultivars are used.

It is also utilized in the process of crop cutting. On application of vermiculite cutting root systems turn to be finely developed. Porous vermiculite granules quickly absorb moisture

and fertilizers and after that give it gradually back creating favorable microclimate for root system nutrition. Vermiculite application time while storing and its activity period are not limited and depend only on its structure preservation (granules porous form). Having added vermiculite into the soil mixture during planting or replanting, it can be utilized until flowerpot soil change.

Thus, vermiculite and its modified forms are widely used in the international agricultural practices for various purposes. The availability of raw materials sources and modified vermiculite developed technology allows of an effective use of this natural material in the agricultural sector, including its application for creating biologically active (nano) chips, enabling complex plant protection on all the stages of rice crop development – "from seed to seed". Owing to its composition, physicochemical and structural features, modified vermiculite is the perfect basis for highly efficient technology development through filling the matrixes with biologically active components of various plant protection means. The question of optimum use of such (nano) chips while adding them to the soil, putting on the seed surface or applying it for grain storage is still acute.

The present work is dedicated to the development of agro-bio (nano) technologies for soya cultivation by making use of biologically active (nano) chips [6,7]. Their use leads to reduction of reactants' application rates, their efficiency increase and exotoxicant pollution level lowering. Vermiculite is one of the types of mineral raw materials being environmentally significant. When introducing biologically active (nano) chips to the soil and putting them on the seed surface, the residual vermiculite facilitates soil structure formation and improves the water-air conditions. Such a development may increase the volume of oil-bearing plants production in the agricultural area, help to launch environmentally safe and competitive products and to preserve such a valuable in the sphere of food industry culture improving the general environmental situation by using the local raw material resources.

2. DISCUSSION

In the course of laboratory research conducted, we have studied the influence of polyfunctional, polycomplex, multicomponent (nano) chips on soya laboratory germination energy and capacity, soya germs growth and development data on the earliest stages of development under the influence of different (nano) coatings. It has been noted that the pre-sowing seed treatment with the developed efficient (nano) chips led to germination energy increase from 72,1 % (control) to 81,0 % and also resulted in laboratory germination capacity expansion from 92,0 % (control) to 99,1 %. Besides, in comparison with the control variant the developed (nano) systems facilitated a considerable increase in stem lengths by 0,9-8,1 cm and germ roots lengths by 0,9-1,7 cm depending on developed (nano) chips composition and germs wet weight. These efficient, polyfunctional, complex (nano) systems were used as seed (nano) coatings during field small-plot experimental research of developed (nano) technologies for pre-sowing soya seed treatment.

Soya seeds coated with the help of pre-sowing seed treatment technology with the selected most efficient (nano) systems have been sown in several small-plot field experiments. Control variant seeds have not undergone any treatment. In the ethalon variants of experiments a pre-sowing soya seed treatment included using separate components, the parts of polyfunctional (nano) systems. In the course of the experiments we have taken the following data into consideration: first shoots emergence, shoots complete emergence, germination capacity, stand density, plants growth dynamics, the numbers of leaves, branches

and beans and their appearance dynamics, plants height up to the first bean (branch), 1000 seed weight. We have been also capturing the biometrical data and calculating soya crop yield indexes.

Considering the calculations and observations made, we have determined that in comparison with the control variant pre-sowing seed treatment with (nano) systems increased the rate of shoot emergence. Thus, the shoot emergence rate was higher when soya seeds had been treated with polyfunctional (nano) systems consisting of NaKMC, modified vermiculite, half the normal amount of Topsin-M and NaKMC, modified vermiculite MVM together with AgroHit and NaKMC, and also modified vermiculite MVM with NaKMC.

Soya plants height measured at various stages during different observation periods had a complicated growth dynamics and varied depending on the experimental variant and the compositions of (nano) system used for pre-sowing soya seed treatment. It should be noted that the last observation records update has shown soya plants height growth in all the experimental variants (in comparison with the control variant). It should be also noted that the number of soya plant leaves grew (according to all the records) when plant seeds had been treated with (nano) structures, consisting of NaKMC, modified vermiculite MVM, half the normal amount of Topsin-M and NaKMC, modified vermiculite MVM together with AgroHit and NaKMC, and also modified vermiculite MVM with NaKMC.

It is also important that, the stem height to the first soya bean increases from 6,2 cm of the control variant to 9,6-11,0 cm when soya seeds are treated with the developed efficient (nano) chips based on modified vermiculite MVM with AgroHit, Topsin and NaKMC.

Besides, the crop disease incidence has been studied using the 5 point rating scale (while estimating biometrical indexes of soya plants). It has been pointed out that in the control variant the disease incidence was about 2,4. In the etalon variants where Topsin M was used, the full amount and half the norm, this indices were 1,0 and 1,2, respectively.

In the experimental variants where soya seeds were treated with polyfunctional complex (nano) systems MVM with NaKMC and half the usual norm of Topsin-M, and also MVM with NaKMC and AgroHit, the injury rate was respectively 1,0; 1,1. This means that in comparison with the control variant (nano) systems decrease the rate of soya bean plant injury, caused by microorganisms, disease producing factors and the resulting indices turn to be on the same level with the etalon data.

Besides, it should be noted that the amount of Topsin M within polyfunctional (nano) systems used for pre-sowing seed treatment with half the norm of fungicides has been reduced twice for (nano) chips composition (in comparison with the manufacturing company recommendations). Notwithstanding this reduction its efficiency remains high when suppressing plant disease pests, this fact offers new social, environmental and economical advantages.

Taking into consideration that the second polyfunctional (nano) system consisting of MVM with NaKMC and AgroHit includes the components obtained from natural non-toxic raw material sources and that it is physiologically active (growth regulating, immunomodulating, fungicidal and containing an additional plant nutrient source) being also environmentally safe, this result is of an enormous importance, for it gives an opportunity to obtain environmentally sound products. The influence of developed efficient (nano) chips for pre-sowing seed treatment on number of side branches, beans and on soya crop yield indices has been studied.

The highest number of side branches has been recorded in the experimental variant where the seeds had been treated with polyfunctional polycomplex physiologically active (nano) systems based on modified vermiculite MVM with NaKMC. The highest number of

soya beans has been recorded in the variants where the seeds had been treated with polyfunctional (nano) chips NaKMC together with modified vermiculite MVM and using half the norm of Topsin-M, or NaKMC together with vermiculite MVM or NaKMC along with modified vermiculite MVM AgroHit. 1000 soya seed weight also depended on the composition of (nano) systems used for pre-sowing seed treatment. In the variants where pre-sowing seed treatment included NaKMC with half the norm of Topsin M and NaKMC together with modified vermiculite MVM and AgroHit, 1000 soya seed weight was 176,2 g and 169,0 g, respectively (in the control variant it was 155,6 g). In the variants where pre-sowing seed treatment included polycomplex (nano) chips usage soya yield index has reached 54,8 c\ha (in the control it was 47,1 c\ ha). Thus, the conducted researches allowed of detecting the most efficient polyfunctional (nano) systems – (nano) chips for pre-sowing soya seed treatment. Application of these complex polyfunctional (nano) chips within the technology for pre-sowing seed treatment facilitated higher field germination, branches, beans number increase, soya yield increase in comparison with the control variant.

3. CONCLUSION

More than that, yield increase due to (nano) chips application for pre-sowing soya seed treatment in separate variants has reached up to 7,7 c\ha depending on polyfunctional (nano) chips composition. It is also significant that in one of the compositions of polyfunctional (nano) chips for pre-sowing seed treatment there are absolutely no chemical preparations, but multicomponent polyfunctional (nano) systems based only on natural mineral derivatives and polymers (poly- and oligosaccharides) with specific features (growth stimulating, fungicidal, immunomodulating and being also an additional plant nutrients source). This fact allows of obtaining environmentally safe products, the term applied to such products is "nanoproduct".

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