Synthesis of Nanomaterials, Nanofertilizers and Research of their Impact on Agricultural Plants

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Abstract

The article discusses the latest scientific innovations in the field of synthesis of nanomaterials, nanofertilizers and their impact on agricultural crops, and also compares the results with the work carried out in this area. It was shown that a nanomaterial - a nanotube with high quality and high structural parameters was synthesized from the gas phase by chemical deposition in the laboratory. The positive effect of the obtained nanotubes on the development of "Gobustan" soft wheat variety was studied and the reasons for the development trend were analyzed. A device has been developed for the production of magnesite nanoparticles (Fe_2O_4), which are used as nanofertilizers in agriculture, increase the productivity of plants, increase the amount of chlorophyll and carbohydrates in plants and are used in various fields of science. The second part of the article examines the effect of nanoparticles on the development of plants (wheat). It was found that nanoparticles of silicon and silicon oxide in a certain concentration affect the pores of the root system of a plant, promote plant growth, and have a positive effect on its productivity. The obtained results confirm the vitality of use of nanomaterials in agriculture and make the use of such materials important for the future development of the agricultural sector.

Keywords: nanomaterial, nanofertilizers, chemical deposition, magnesite, nanoparticles.

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Nanomaterialların, nanogübrələrin alınması və kənd təsərrüfatı bitkilərinə təsirinin tədqiqi

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Xülasə

Məqalədə nanomaterialların, nanogübrələrin sintez edilməsi və onların kənd təsərrüfatı bitkilərinə təsiri barədə son elmi yeniliklər araşdırılmış, alınan nəticələr bu sahədə aparılan işlərlə müqayisə edilmişdir. Alınan nanoboruların "Qobustan" yumşaq buğda sortunun inkişafına müsbət təsiri araşdırılmış və inkişaf tendensiyasının səbəbləri təhlil edilmişdir. Kənd təsərrüfatında nanogübrə kimi istifadə edilən, bitkinin məhsuldarlığını yüksəldən, bitkidə xlorofil və karbohidratın miqdarını artıran, həm də elmin müxtəlif sahəsində tətbiqini tapan maqnetit (Fe_2O_4) nanohissəciyin alınması üçün qurğu hazırlanmışdır. Nanohissəciklərin bitkilərin (taxılın) inkişafına təsiri araşdırılmışdır. Müəyyən olunmuşdur ki, silisium və silisium oksid nanohissəcikləri müəyyən edilmiş konsentrasiyada bitkinin kök sistemində olan gözcüklərə təsir edərək bitkinin inkişafını asanlaşdırır, onun məhasuldarlığına müsbət təsir edir.

Açar sözlər: nanomaterial, nanogübrə, kimyəvi çökdürmə, maqnetit, nanohissəcik.

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Синтез наноматериалов и наноудобрений, исследование их воздействия на сельхозкультуры

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Аннотация

В статье рассматриваются последние научные инновации в области синтеза наноматериалов и наноудобрений, их влияние на сельскохозяйственные культуры, а также сравниваются результаты с работами, проводимыми в этой области. Изучено положительное влияние полученных нанотрубок на развитие сорта мягкой пшеницы «Гобустан» и проанализированы причины тенденции развития. Разработано устройство для производства наночастиц магнетита (Fe2O4), которые используются в качестве наноудобрений в сельском хозяйстве, повышают продуктивность растений, увеличивают количество хлорофилла и углеводов в растениях и используются в различных областях науки. Исследуется влияние наночастиц на развитие растений (пшеницы). Обнаружено, что наночастицы кремния и оксида кремния в определенной концентрации влияют на поры корневой системы растения, способствуют росту растения и положительно влияют на его продуктивность.

Ключевые слова: наноматериал, наноудобрения, химическое осаждение, магнетит, наночастицы.

Introduction

Nanotechnology is the production of nanomaterials, creation of nanostructures on their basis, and methods of manipulating nanoobjects. Currently, nanomaterials are widely used in physics, chemistry, biology, agriculture, engineering, and medicine. The main reason for the interest in nanomaterials is that the particle size of a substance has significantly decreased compared to the critical size, which led to a significant change in their properties. The critical particle size ranges from 1 nanometer to 100 nanometers for many substances, while changes in their properties occur abruptly. Materials are also called nanomaterials because this measurement, in which the measurement effects are observed, is in the nano order. It was found that the main properties and stability of nanomaterials directly depend on the method of their production. In the process of obtaining nanoparticles, it is necessary to take into account their high reactivity and instability. When these conditions are not taken into account, they lose their basic properties and become aggregated by interacting with the environment. The production of nanostructures is based on two concepts. One of those is the bottom-up concept (condensation; combination of atoms, ions, molecules) and the other is the top-down concept. The bottom-up concept means creating an ordered structure by combining individual atoms. This can be done as a result of self-assembly or some sequence of catalytic chemical reactions. Such processes are very common in biological systems and are almost natural for the survival of living things. For example, biological catalysts called enzymes assemble amino acids in such a sequence that they form living tissue. The concept of "top-down" implies the creation of nanostructures with a gradual decrease in the size of a macro object or a macro-size structure. The methods used to obtain nanostructures are conventionally divided into chemical (nanoparticles are obtained by chemical reactions) and physical (obtained by a physical process) methods. Bottom-up technology permits to assemble nano-sized objects from individual atoms and molecules. Condensation is often used in this technology. Nanostructures; carbon nanotubes, fullertenes, nanoclusters can also be obtained by condensation. This technology is called epitaxy. Epitaxy means the sequential accumulation of another crystal on one crystal.

Technology of the production of nanomaterials and nanofertilizers.

Carbon nanotubes are cylindrical structures several microns long formed by bending one or more layers of graphite. The carbon atoms on the pipe surface are at the top of the regular hexagon, and the end is connected to the regular hexagon. Carbon nanotubes are formed by the chemical conversion of carbon at high temperatures. Depending on the synthesis method, it is possible to obtain single-layer, double-layer, multi-layer, etc. nanotubes. In the laboratory, carbon nanotubes with high quality and high structural parameters were synthesized by the method of chemical vapor deposition (CVD) (Figure 1).

Aerosol chemical deposition was used to synthesize carbon nanotubes. CVD - the system consists of a horizontal quartz reactor (2 m long and 45 mm in diameter), covered with an electric furnace 35 cm long. This method is based on spraying the solution into a reactor in the form of an aerosol and decomposing it at high temperatures. Carbohydrate liquids were used as a solution. The starting material ranges from 40 to 60 ml. Productivity 2.0 - 2.5 g/h, depending on the experimental conditions and the volume of raw materials. As a result of the development of the laboratory system, the productivity was 20.0 g/h.

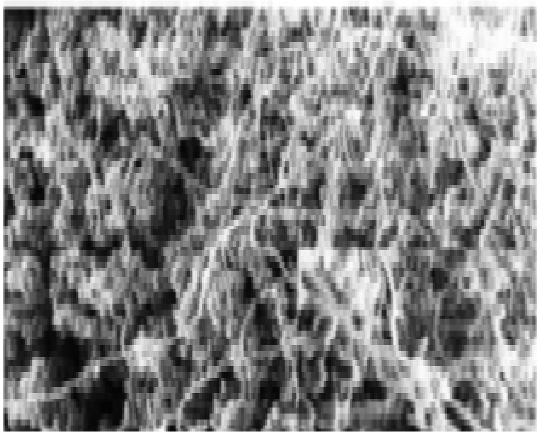
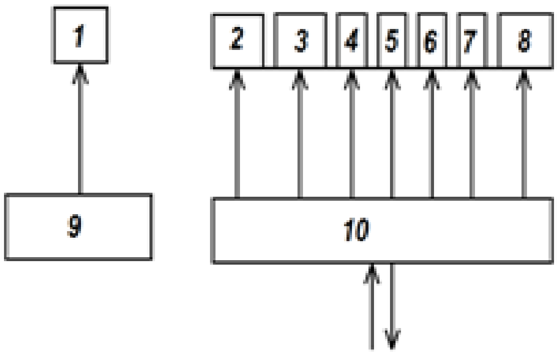


Figure 1 – SEM description of carbon nanotubes

A mixture of organic solvents such as cyclohexane, alcohol, acetone, benzene with ferrosen was used, and Ar/H_2 gas was used as the transport gas. The system is isolated from air and filled with argon gas. A high-frequency ultrasound device was used to obtain the aerosol. After reaching the required temperature, the aerosol is introduced into the system at a speed of 850 sm^3/min. H2 gas is introduced into the system during synthesis. After the deposition and cooling process, synthesized carbon nanotubes are obtained from equipment pipes without the use of special chemical methods. This method was used to grow multilayer carbon nanotubes with a diameter of 10-85 nm and a small percentage of 0.85-1.14 nm [1-3].

The main part of the device for the production of most nanomaterials is the reactor. The most important device in the reactor is the plasmatron. The principle of operation of any plasmatron is the same: an electric arc occurs between a solid material cathode and an intensively cooled anode. The working medium ionizes it, releasing it from the electric arc, and plasma, the fourth state of matter, is obtained at the output of the plasmatron. In this case, ordinary air, alcohol vapors, water, etc., can be used as a working medium. Copper with an inner hole diameter of 1.9 mm was used as the anode. Water or ordinary antifreeze is used as a coolant. An electromagnetic coil is placed along the nozzle to stabilize the plasma flow and prevent erosion of the anode. A tungsten rod with a diameter of 4 mm is taken as the cathode (the rod used as the anode material is pushed through). A working fluid under a pressure of 1.5 atmospheres is used to cool the cathode. A household electric heater with a power of 4.5 kW can be used as a ballast resistor [4].

It should be noted that when the arc is ignited, you need to touch the cathode to the anode and quickly fix at a distance of 3 mm. The block diagram of the device is shown in Figure 2.



1. *Anode*
2. *Cathode holder cover*
3. *Cathode holder*
4. *Intermediate layer*
5. *Screw*
6. *Tungsten cathode*
7. *Thread holder*
8. *Stabilization support*
9. *Anode block*
10. *Cathode block body*

Figure 2 – Block diagram of a device for the synthesis of nanoparticles and nanostructures

Magnetite nanoparticle (Fe_3O_4) and its production technology: Fe_3O_4 nanoparticles have magnetic-physical properties and are mostly black in color. It is currently used in the production of nanomaterials, electrical engineering, pharmaceuticals, national security systems, information technology, biotechnology, and agriculture.

Fe_3O_4 is used in agriculture as a nanofertilizer, which increases the productivity of plants, increases the amount of chlorophyll and carbohydrates in the plant. It also affects humic acids and soil pH. Magnetic nanoparticles in small concentrations increase the plant's resistance, make it resistant to cold and thirst, act as a cofactor of enzymes (resistant to high temperatures), and participate in the formation of intermediate metabolites [5].

There are many methods for synthesizing magnetite nanoparticles, the most common of which is the chemical method. In this method, 6 grams of $FeCl_3.6H_2O$ and 3 grams of $FeSO_4.7H_2O$ are mixed in 100 ml of an aqueous solution. Next, 25% ammonium hydroxide (NH4OH) is added to the mixture and stirred again at 500 ° C for 2 hours. The resulting solution is placed in a centrifuge and rotated at 60 rpm. In this case, the aqueous solution is separated, and only magnetite nanoparticles remain. It was found that the size of magnetite nanoparticles is in the order of 10-20 nm. In the research also used 20 nm silicon and silicon oxide nanoparticles and magnetite nanoparticles with magnetic-physical properties.

Nanoparticles and their effect on plant growth

A reliable food supply is one of the main conditions for the economic and social stability of any country. Consequently, to meet the population's demand for food and industrial raw materials at the current level, it is necessary to increase agricultural productivity. A positive solution to this issue has always been relevant for the agricultural sector at all times.

Increasing the yield of agricultural crops and improving the quality of products primarily depends on the study of the interaction between fertilizers, soil and plants in the process of mineral nutrition, taking into account their biological properties, protecting soil fertility and determining the optimal rates of fertilizers for the return of nutrients taken from the soil, the use of scientifically based fertilization systems [6].

The area shown in Figure 3 was selected as the study area and was divided into six equal portions, each 12.5 m long and 3.6 m wide, of which 3 portions were used as the study area.

Figure 3 – The area selected for the study

That is, the studies were carried out on plots with an area of 45 m^2 each. In each study field, 1.15 kg of Gobustan soft wheat seeds were sown. The seeds are first washed with plain water, then with distilled water and dried on filter paper. Then the seeds were divided into 3 parts and mixed with water, adding a 20 nm silicon nanoparticle (Si) to the first part and a silicon dioxide (SiO_2) nanoparticle to the second part, in which 10 mg, 50 mg and 100 mg nanoparticles are added to 100 ml of water.

Watering was carried out after sowing. Watering after sowing is called sprinkler watering. Unlike other methods, spraying should

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be carried out by strip or furrow method. [7]. Furrow irrigation is also used to flush saline soils. Germination occurs 13-27 days after sowing. [8]. In our case, germination was observed after 13-21 days (Fig. 4).

Figure 4 – Wheat germination phase

It was found that even if the soil moisture is not normal, there are no difficulties in the germination of such plants. Table 1 shows the measured wheat root lengths for November and December.

Table 1 – The measured wheat root lengths for November and December.

Area	Root length (sm)	
	November	December
Ordinary	5	7
Si	6,7	11,5
SiO_2	8	12,9

As can be seen from the Table 1, the length of root of wheat treated with nanoparticles of silicon and silicon dioxide and measured within two months were longer than the root of ordinary wheat. As can be seen, silicon dioxide has a better effect on the development of the wheat root. In the experiment, silicon and silicon oxide nanoparticles in 3 different concentrations were given to each field separately. At the same time, it was found that the increase in the concentration of nanoparticles does not increase the development of the root system of the plant, which is associated with the lagging of root growth. It is known that nanoparticles acting on root pores expand them. As a result, water and nutrients can more easily enter the plant from the expanded part. When the concentration of nanoparticles is high, the nanoparticles can fill the pores and cause clogging. Thus, it is difficult for the plant to absorb water and nutrients.

In our experiments, we also used magnetite nanoparticles and nanotubes 30-50 nm in size. Magnetite nanoparticle behaves in the same way as nanofertilizer, and increases plant productivity by increasing the amount of chlorophyll in the plant, as well as carbohydrates, affecting the height of the plant. At low concentrations, a magnetite nanoparticle plays a key role, increases the plant's resistance, makes it resistant to cold and thirst, acts as a cofactor of enzymes (resistant to high temperatures), and participates in the formation of intermediate metabolites. Experiments have shown that nanotubes have a significant effect on the growth rate and height of plants compared to nanoparticles. Experiments on wheat have led to the conclusion that a single-walled nanotube in an aqueous solution increases its height by 20% compared to the usual case.

Conclusion

A new device for the production of nanoparticles and nanostructures has been developed. Due to the new device it is possible to obtain nanoparticles of any metal, as well as nanotubes and nanostructures of a certain diameter, as well as to control their size. It was found that nanoparticles of silicon and silicon oxide at a certain optimal concentration, acting on the pores in the root system of the plant, expand them, facilitating the transfer of water and nutrients into the plant and causes its development. When the concentration of nanoparticles exceeds 100 mg / l, it negatively affects the crops and weakens their development.

REFERENCES

1. Electrosam.ru/glavnaya/ielektrotehnika/uglerodnye-nanotrubki/
2. **Eatemadi A., Daraee H.** etc. Carbon nanotubes: properties, synthesis, puzification and medical application // Nanoscale researh letters. 2014. № 393. Pp.126-139 *(in English)*.
3. **Ganesh E.N.** Single walled and multi walled carbon nanotube srtucture // *Synthesis and application*. IIYTEE ISSN:2278-3075, v.2. ISSUE 4, March 2013. Pp.311-320.
4. **Munra K., Kawase M.** Nano-reactor for producing high performance nanomaterials // *Chemical Engineering Science* v.62. ISSUES 18-20 September-October 2007. P 5655-5660
5. https://doi.org/10.18799/24131830/2019/812222
6. **Hacıməmmədov İ.M., Təlai C.M., Kosayev E.M.** Torpaq bitki və gübrələrin aqrokimyəvi analiz üsulları. 2016, Bakı: *"Müəllim"*. 132 s. *(in Azerbaijani).*
7. **Hacıyev C.Ə., Allahverdiyev E.R., İbrahimov A.Q.** Suvarma əkinçiliyi. 2012 Bakı: *"MBM"* nəşriyyatı. 224 s. *(in Azerbaijani).*
8. **İbrahimov A.Q., Qurbanov F.N.** Seleksiya və toxumçuluq. 2012 Bakı: *"Elm"*. 382 s.

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