Generalization of the results on the effect of selenium nanocomposites on the interaction of potatoes with the ring rot disease pathogen

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The aim - Investigation of the effect of selenium nanocomposites on the viability of phytoptogens and plants in order to develop drugs for the improvement of cultivated plants.

Materials. *Selenium nanocomposites (Se NCs)*

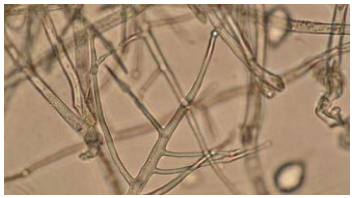
1. Nanocomposite (AG/Se Nc) based on arabinogalactan isolated from Siberian larch *Larix sibirica*. The content of Se 1.23%, 3.4%, 5.92%, 6.4%.
2. Nanocomposite (ST/Se Nc) based on starch. The content of Se 1.46%.
3. Nanocomposite based on carrageenan (CAR/Se Nc) The content of Se 2.0%, 3.76%.

Objects:

Potato plants *in vitro*, seeds of soybeans, peas, potatoes

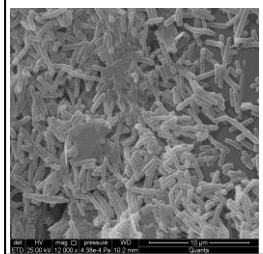
Clavibacter sepedonicus (*Cms*) bacterial that causes circular potato rot disease

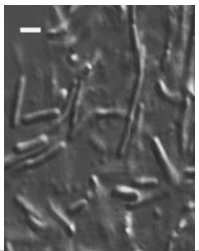
fungus *Phytophthora cactorum*



Soil bacterial:

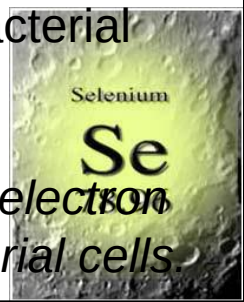
Acinetobacter guillouiae;
Rhodococcus erythropolis;
Pseudomonas oryzihabitans





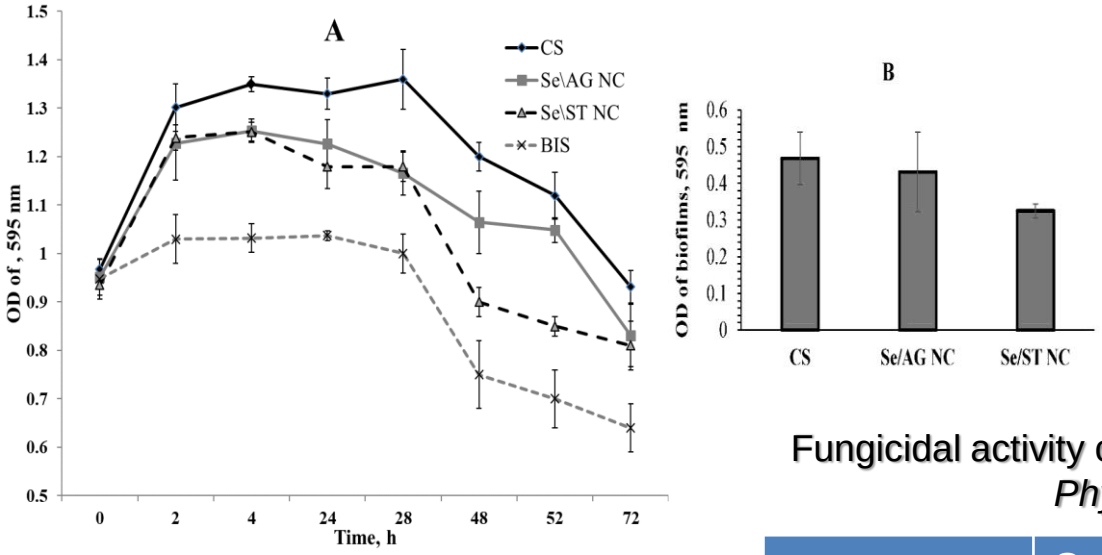
Methods:

1.Synthesis of selenium nanocomposites;
2.Energy dispersive X-ray microanalysis of Se NCs and seven elements including Se in Potato Plant Samples;
3.X-ray Phase Analysis of Se NCs;
4.Transmission electron microscopy of Se NCs;
5.Cultivation of plants and microorganisms *in vitro*;
6.The optical density of the bacterial suspension;
7.Bacterial biofilm formation,
8.Transmission and scanning *electron microscopy of plant and bacterial cells.*

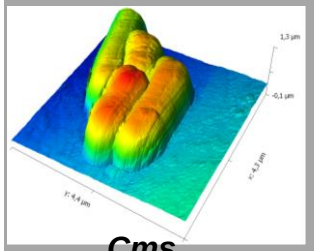


Results. Effect of Se NCs on *Clavibacter sepedonicus* and on fungus *Phytophthora cactorum*

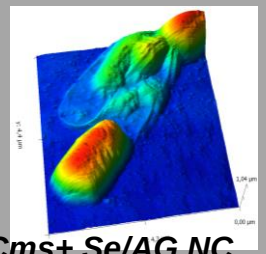
Effect of Se NC on the growth (A) **and biofilms** (B) **of *Cms***. OD-optical density



Scanning electron microscopy of bacteria *Cms*

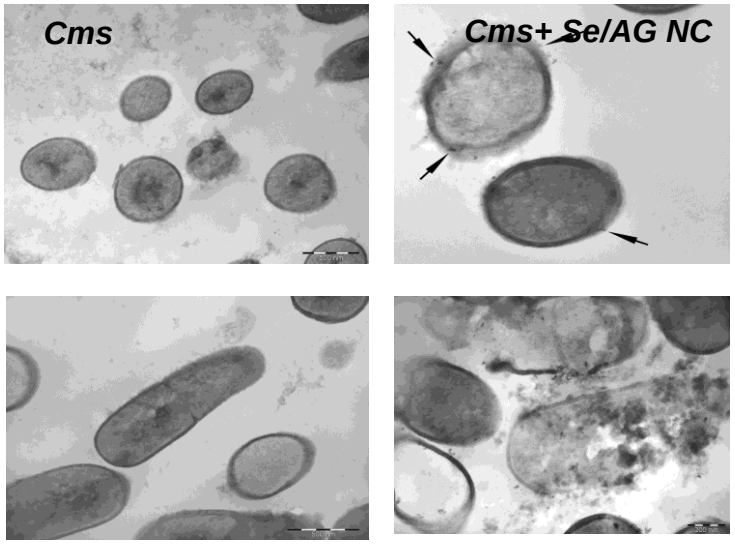


Cms



Cms+ Se/AG NC

Scanning electron microscopy of bacteria



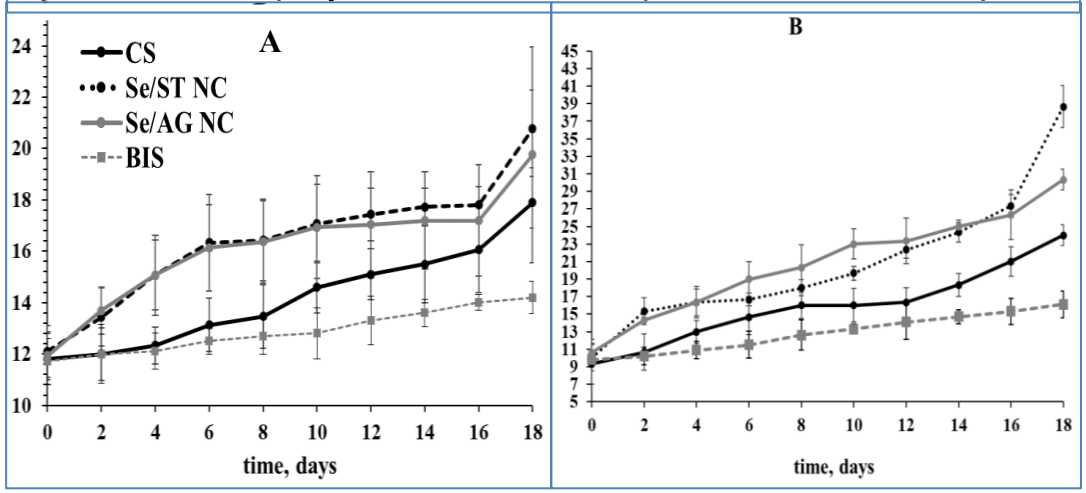
Fungicidal activity of selenium (Se) nanocomposites against fungus *Phytophthora cactorum* VKM F-985

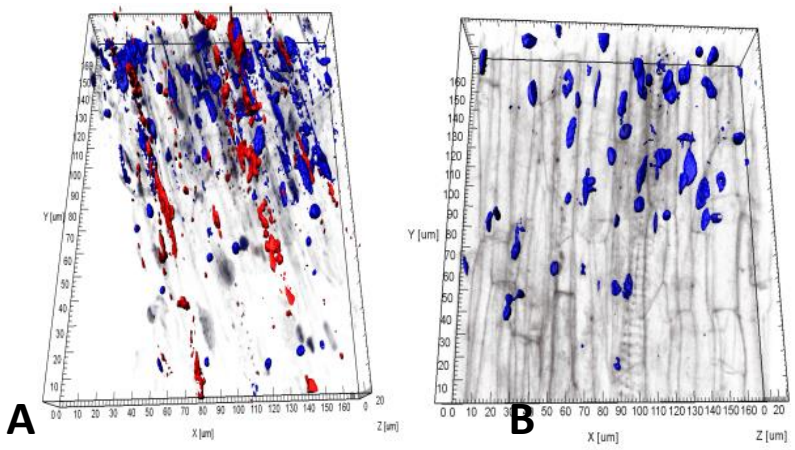
Ingredient	Concentration, µg/ml	Inhibition value, I, %*			EC_{50}, µg/ml
		4 day	7 day	10 day	
Se/AG NC	50	19	20	26	74
	100	25	33	34	
	200	50	47	43	
	300	56	60	60	
Se/ST NC	35	6	17	11	58
	70	12	23	21	
	139	19	33	40	
	208	37	37	47	
Se/CAR NC	39	0	13	9	78
	78	19	20	23	
	156	25	30	30	
	234	50	47	49	
Fludioxonil	10	46	18	12	10.8

* Presented are the average values; the standard deviation did not exceed 0.03 of the presented values.

Results. Effect of Se NCs on potato plants *in vitro* and seed germination

Effect of treatments by Se/AG and Se/ST NCs on the length (A, y – length of plants, cm) and number of leaves in potato plants *in vitro* (B, y – number of leafs). CS — control samples





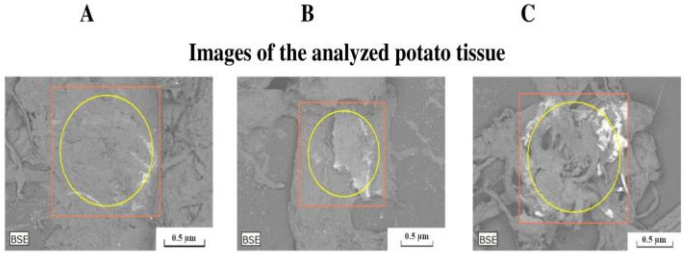
Increase in ROS production in potato tissues after their treatment with NC Se/AG (6.4%). Staining on ROS (CellROX deep red reagent, red) and nuclei (DAPI, blue); confocal microscopy, 3D reconstructions. control samples; B – tissue areas with numerous large ROS clusters after treatment of plants with NC Se/AG (6.4%)

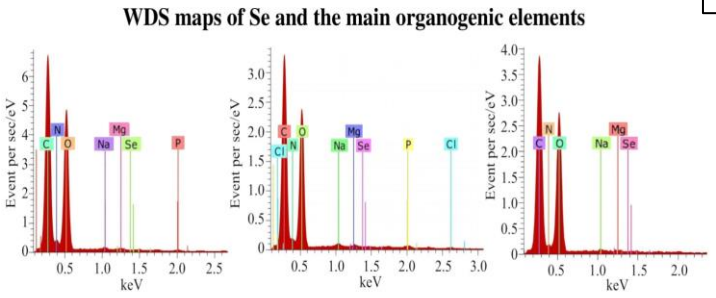
	Variant	Shoot length, см	Root length, см	Shoot mass, g	Root mass, g
Radish	Control	1.85±0.06	8.11±0.23	0.03±0.0	0.04±0.0
	Se/AG NC	1.71±0.06	8.90±0.21*	0.03±0.0	0.04±0.0
	Se/ST NC	1.89±0.06	8.84±0.21*	0.03±0.0	0.04±0.0
	Se/CAR NC	1.78±0.05	8.86±0.24*	0.03±0.0	0.04±0.0
Soybean	Control	2.07±0.12	2.13±0.14	0.07±0.0	0.05±0.0
	Se/AG NC	1.9±0.09	2.54±0.14	0.06±0.0	0.05±0.0
	Se/ST NC	3.64±0.21*	4.02±0.33*	0.10±0.01*	0.06±0.0
	Se/CAR NC	3.57±0.21*	6.16±0.51*	0.10±0.01*	0.1±0.01*
Potato	Control	2.04±0.1	–	0.27±0.02	–
	Se/AG NC	2.2±0.11	–	0.32±0.02	–
	Se/ST NC	1.9±0.08	–	0.26±0.02	–
	Se/CAR NC	3.12±0.15*	–	0.46±0.04*	–

Effect of selenium NCs in natural matrices on the length and weight of the shoots and roots of radish and soybeans and the length and weight of potato seedlings (data are represented as $M \pm SE$. * significant differences from the control at $p < 0.05$, $n = 3$)

Results. Effect of Se NCs on selenium accumulation in plant tissues and on soil microflora

Results of energy-dispersive X-ray spectroscopy microanalysis (EDXMA) of infected *Cms* potato plant tissues untreated (A) and treated with Se/ST (B) or Se/AG (C) NCs. WDS—Wavelength-Dispersive Spectroscopy. Shown as an example of typical data from one of the experiments





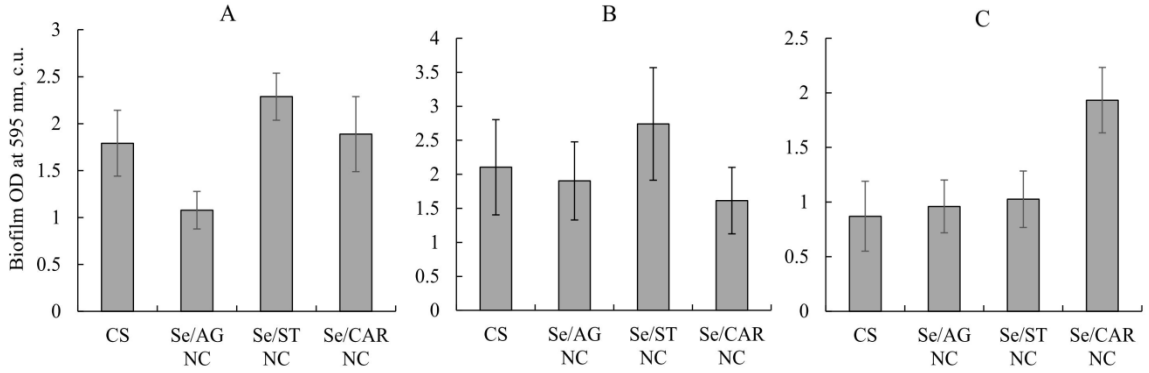
Datasheets

Element	Content, %
Oxygen (O)	40.25
Carbon (C)	51.83
Nitrogen (N)	7.31
Sodium (Na)	0.27
Phosphorus (P)	0.17
Magnesium (Mg)	0.17
Selenium (Se)	0.00
Total	100

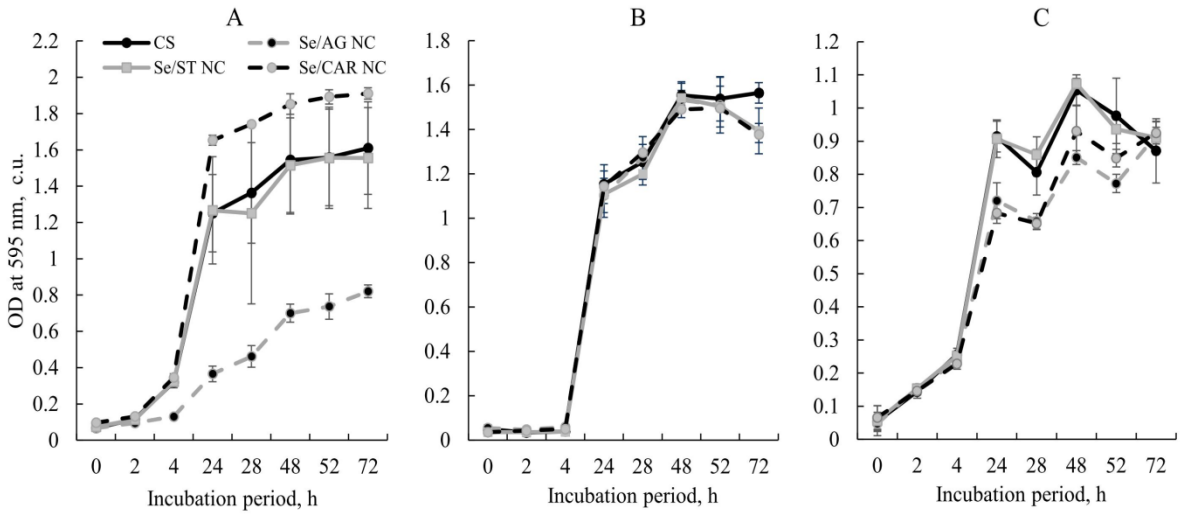
Element	Content, %
Oxygen	39.53
Carbon	52.46
Nitrogen	6.91
Sodium	0.38
Phosphorus	0.51
Magnesium	0.21
Selenium	0.00
Total	100

Element	Content, %
Oxygen	40.51
Carbon	53.03
Nitrogen	5.90
Sodium	0.18
Phosphorus	0.29
Magnesium	0.09
Selenium	0.00
Total	100

Effect of Se NC treatment in natural matrices on the biofilm formation of soil bacteria *A. guillouiae* (**A**), *R. erythropolis* (**B**), and *P. oryzihabitans* (**C**)



Effect of NC Se treatment in natural matrices on the growth dynamics of soil bacteria *A. guillouiae* (A), *R. erythropolis* (B), and *P. oryzihabitans* (C). CS – control samples



Conclusions

* Se NCs reduce the viability of the phytopathogenic bacterium *Clavibacter sepedonicus* (reduces cell viability and their ability to form biofilms) and phytopathogenic fungi of the *Phytophthora*.
* Se NCs stimulate the growth and development of potatoes *in vitro*, the germination of seeds of cultivated plants (soybeans, peas, potatoes). Experiments in plants have shown a stimulating effect from NCs on the plant biometric indicators and a decreased harmful effect from bacterial infection. Nanocomposites activate the antioxidant system of plant cells, affect the activity of peroxidase and products of lipid peroxidation.
* X-ray microanalysis was shown that after the treatment of plants with Se NCs, Se did not accumulate in plant tissues. In addition.
* Se NCs did not inhibit the viability of soil microorganisms *Acinetobacter guillouiae, Rhodococcus erythropolis, Pseudomonas oryzihabitans*, which indicates a relative safety for real use.

These results allow us to consider nanocomposites as a plant development stimulator for agricultural crops.

Thank you for attention!