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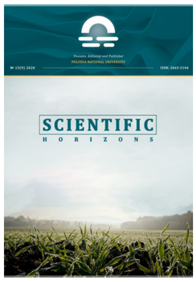

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Protection of seed potatoes against virus infections in the field conditions of Polissia of Ukraine

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Abstract. Viral diseases pose a significant problem for potato seed production, therefore, to ensure high-quality characteristics of seed material, it is necessary to research the development of new methods of their control. The study aimed to determine the effectiveness of the integrated application of elements of the system of protection of basic seed potato plantations from viral diseases using mineral oils, top removal and biological preparations based on nanoparticles in the South of Polissia of Ukraine. The

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study demonstrated that the treatment of potato tubers and spraying of plants during the growing season with a nanopreparation of biological origin increased the yield of seed potatoes of Myroslava variety compared to the control without treatment by 2.7 t/ha or 6.94 %, and Fotyniia variety – by 2.6 t/ha or 6.9 %. The use of potato tops desiccation, treatments and mineral oil provided an increase in the yield of Myroslava by 3.3 t/ha or 9.5%. The use of potato tops desiccation and potato treatments during three growing seasons, according to the results of the visual method of plantation assessment, contributed to a 2.9% reduction in the damage of Myroslava potato variety plants by virus diseases, and 2.6% in Fotyniia variety, while the damage of plants in the control varieties was 4.5% and 4.7%, respectively. The results of the enzyme-linked immunosorbent assay of potatoes in the post-harvest period showed that treatment of vegetative potato plants with the nanopreparation reduced the infection of seed potatoes with *Potato virus Y* (PVY) by 0.5 %, while the infection of plants with PVY virus infection in the control without treatment was 1.0 %. Based on the results of the research, elements of the system of integrated application of a multicomponent nanopreparation of biological origin, spraying of plantations with insecticides and mineral oil and desiccation of potato tops to combat viral diseases of pre-basic, basic and certified seed potatoes were proposed

Keywords: yield; viral diseases; *Potato virus Y* infection; nanoparticle-based preparations; mineral oil

INTRODUCTION

An important problem in potato growing is the high susceptibility of potatoes to viral diseases. Potatoes can be affected by more than 50 viruses. For instance, when potato plants are infected with the PVY virus, the yield reduction can reach up to 80% (Kreuze *et al.,* 2020; Jones, 2021). Studies evaluating the yield of potatoes derived from PVY-infected seed determined that 1% PVY infection in seed resulted in a 0.18 t/ha reduction in yield, marketability, and tuber size (Torrance & Talianksy, 2020). The spread of the PVY virus in the United States has been increasing since 2000 (Mondal *et al.,* 2023). In Ukraine, a significant increase in the spread of potato diseases caused by PVY alone and with pathocomplexes of other viruses has been detected. Measures to limit the spread of PVY in potato plantations include quality control of seed potato lots, selection of resistant varieties, early phytosorting to reduce the amount of harmful inoculum in the field and the destruction of vector vectors (Demchuk *et al*., 2024).

The results of many studies demonstrate the effectiveness of the use of mineral oils together with other methods of protecting seed potatoes from re-infection with PVY virus infection in the field. G.V. Baliota and C.G. Athanassiou (2023) presented an in-depth analysis of the insecticidal properties of mineral oils. The most effective method was to combine the use of mineral oils with insecticides. Mineral oils are harmless to the environment and do not cause resistance in target insect pests. T.D.B. MacKenzie *et al.* (2022) proved that the use of mineral oils increases the retention of a pyrethroid insecticide in potato leaves for a longer period compared to insecticides that were applied without the addition of mineral oils, which confirms the positive synergistic effect of combined spraying of plantations to reduce the spread of PVY.

Field trials conducted by J.L. Rolot *et al.* (2021) in the Ardennes region of Belgium using insecticide treatments with mineral oil, insecticides and mixtures of insecticides showed that the use of mineral oil is an effective way to protect seed potato crops from the spread of PVY. However, this protection may not be sufficient. The study determined that the use of insecticides was ineffective, especially pyrethroid drugs. Systemic insecticides provided additional protection if applied in a mixture with mineral oil during the period of high activity of winged aphids. Early destruction of the aboveground vegetative mass of plants reduced the presence of PVY infection in the seed tubers. Mulching plantations treated with mineral oil with straw increase the level of protection of potato crops. It can also reduce the number of sprayings required.

A. Bondarchuk *et al.* (2020) also proved that an effective agronomic measure to maintain high-quality characteristics of seed potatoes is the removal of potato tops, which significantly reduces the number of tubers infected with viruses in the current year due to the fact that virus particles do not have time to penetrate the tubers of the new crop. The probability of virus infection of plants is significantly reduced with a decrease in the number of insect vectors and their activity with the use of insecticides and mineral oils. O. Vushnevska *et al.* (2021) revealed the best way to preserve the quality of potato seed material, which reduced the content of viral infection in seed potatoes, which was achieved by using desiccation of potato tops on the 20th day after flowering of potato varieties Myroslava, Predslava and Alliance and the use of Sunspray mineral oil. Biological products with antiviral effects can be an alternative environmental element of the system for combating viral diseases. S.M. Talebi and M. Ghorbanpour (2023) demonstrated that nanopreparations are used as fertilisers and can eliminate the effects of environmental stress on plants. B. Rashwan *et al.* (2023) proved that the treatment of plants with NP Zn resulted in a significant improvement in their growth parameters, yield and nutritional qualities of tubers.

The issues of antiviral properties of a biological multicomponent micronutrient preparation with nanoparticles and NP Ni for the protection of seed potatoes from potato diseases remain poorly understood. The use of mineral oil and insecticide treatments for basic seed potatoes in the southern Polissia zone of Ukraine is also insufficiently studied. Therefore, the study aimed to develop elements of control of potato virus infections using nanopreparations, insecticide treatments in combination with mineral oil and potato tops desiccation.

MATERIALS AND METHODS

The research was conducted in the fields of scientific crop rotation at the Institute of Potato Growing of the National Academy of Agrarian Sciences of Ukraine. In 2021-2023, certified seed potatoes of super-superelite, superelite and elite classes, improved by biotechnology, were planted. The field experiment was conducted following the provisions of A.A. Bondarchuk *et al.* (2019). The scheme of the experiment is shown in Table 1.

***Table 1**. Experiment design*

Variant number	Experiment variants
1	Control 1. Treatment of tubers with Celest® Top, 0.7 l/ha.
2	Seed treatment with Avatar-2 Protection, 300 ml/ha; plant treatment* with Avatar-2 Protection, 200 ml/ha
3	Treatment of seed material with Celest® Top, 0.7 l/ha and NP Ni, 20 ml/l of water; treatment of plants* with NP Ni, 20 ml/l of water
4	Control 2. Treatment of seed material with Celest® Top, 0.7 l/ha; destruction of tops with Reglon® Super 150 SL, 2.0 l/ha
5	Treatment of seed material with Avatar-2 Protection, 300 ml/ha; treatment of plants* with Avatar-2 Protection, 200 ml/ha; destruction of tops with Reglon® Super 150 SL, 2.0 l/ha.
6	Treatment of seed material with Celest® Top, 0.7 l/ha, NP Ni; 20 ml/l of water; treatment of plants* with NP Ni, 20 ml/l of water; destruction of tops with Reglon® Super 150 SL, 2.0 l/ha.
7	Control 3. Seed treatment with Celest® Top, 0.7 l/ha; plant treatment* with OLEMIX® 84 k.e. mineral oil, 1.0 l/ha; tops destruction with Reglon® Super 150 SL, 2.0 l/ha.
8	Treatment of seed material with Avatar-2 Protection, 300 ml/ha; treatment of plants* with Avatar-2 Protection, 200 ml/ha; treatment of plants* with OLEMIX® 84 h.e. mineral oil, 1.0 l/ha; destruction of tops with Reglon® Super 150 SL, 2.0 l/ha.
9	Treatment of seed material with Celest® Top, 0.7 l/ha, Ni nanoparticles, 20 ml/l of water; treatment of plants*, 20 ml/l of water; mineral oil OLEMIX® 84 k.e., 1.0 l/ha; destruction of tops with Reglon® Super 150 SL, 2.0 l/ha.

***Note:** treatment of plants during the growing season with Avatar-2 Protection, Olemix® 84 k.e. mineral oil, and NP Ni was done during the plant development phase: seedlings (BBCH 1-10) and budding (BBCH 51-59)*
***Source:** compiled by the author*

All experimental variants except 1 (control) used drugs as the base model: Engio® 247 SC hp, 0.18 l/ha; Fastak® 100 EC, 0.07-0.10 l/ha; Karate® Zeon 050 EC, 0.1-0.2 l/ha; Metaxyl® ZP, 2.5 kg/h; Shirlan® 500 SC, 0.3 l/ha; Nativo® 75 WG, 0.35 kg/ha. Spraying of potato seed material and spraying of plants was carried out with a manual sprayer, with a water rate of 10 l/t for seed treatment and 170 l/ha for plant treatment. For phenological studies, biometric measurements, and determining the timing of various types of technological operations, including desiccation of potato tops, the international scale of plant growth and development BBSN was used, which defines the following phases: seedlings (BBCH 1-10), budding (BBCH 51-59), flowering (BBCH 60-69), "green berryЭ (BBCH 70-79), technical maturity (BBCH 91-99).

The experiment was replicated four times. The total area of the variant is 22.5 m^2, and the accounting area is 11.25 m^2. The experiment was conducted by the overlapping method during 2021-2023, i.e. the seed material was not changed every subsequent growing season. The method of planting potatoes is 75×20 cm with a plant density of 66.7 thousand units/ha. The cultivation technology is generally accepted for seed potato plantations in the Polissia zone of Ukraine. In the spring, the field was ploughed and cultivated, and ridges were formed at the beginning of potato germination with a milling cultivator. Mineral fertilisers were applied in the form of nitroammophoska at a rate of 500 kg/h in physical weight or active ingredient: $N_{80}P_{80}K_{80}$ in kg/h with the addition of potash fertiliser at a dose of K_{30} kg of active ingredient per 1 ha. Fertilisers were applied locally in the rows during potato planting, and ammonium nitrate – N_{20} kg/h of active ingredient was applied in the phase of growth and development of potato plants – plant sprouts.

The experiment used NP Ni and the Avatar-2 protection preparation. The composition of Avatar-2 protection includes the following chemical elements: S, Cu, I, Al, Ni, Bi and V, Mg, Zn, Fe, Mn, Co, Mo, La, Ti, Se, Ge, Si, B and Ce, produced by nanotechnology and in organic compounds with citric acid. Avatar-2 Protection is registered in Ukraine and certified by Organic Standard LLC. The preparation based on NP Ni contains NP as a dispersed phase and 1.5-2.5% citric acid solution as a dispersion medium. The dose of the preparation based on NP Ni is specified by the manufacturer (Avatar Research and Production Company LLC).

Visual assessment of the symptoms of viral diseases on potato plants was carried out following the Guidelines for field assessment of seed potato plantations (Furdyha *et al*., 2023). Desiccation of the aboveground mass of plants was carried out during the period of maximum formation of seed tubers no more than 28-60 mm in size by the largest transverse diameter of 70-80% of the structure of the entire crop. Potato tops were removed by spraying the plants with Reglon® Super 150 SL with 2 treatments – the first treatment of tops at a dose of 0.8 l/ha, the second – at 1.2 l/ha. Spraying of the plantations with mineral oil OLEMIX® 84 k.e. was performed along with the application of insecticides and fungicides at a dose of 1.0 l/ha per 300 l/ha of water. The yield was determined from each variant and each replication. Before harvesting, the number of healthy and diseased plants was determined, and the places of possible exceptions to sowing were identified.

Statistical processing of the experimental data was done based on a one-factor analysis of the variance of the results of the field experiment (Bondarchuk *et al.,* 2019). The yield increase was calculated relative to the controls following the experimental design (Table 1). The content of virus infection in potato plants was determined by indexing tubers in the post-harvest period according to the method of M.M. Furdyha *et al*. The detection of PVY virus infection in potato tubers was carried out by a solid-phase enzyme-linked immunosorbent assay (ELISA) (double sandwich version, DAS-ELISA) using commercial test systems from LOEWE, Germany. The results of the enzyme-linked immunosorbent assay were read on a Termo Labsystems Opsis MR photometer (USA) with the Dunex Revelation Quicklink software at 405 nm. Statistical processing of the results of optical density in the wells of the polystyrene plate with samples was carried out by descriptive statistics, with the establishment of mean and standard deviations of the data. For each plate, the threshold value of optical density was set separately to determine the positive results of the enzymatic reaction different from the background value according to the recommendations (Technical Information. ELISA Data Analysis). The authors adhered to the standards of the Convention on Biological Diversity (1992) and the Convention on Trade in Endangered Species of Wild Fauna and Flora (1979).

RESULTS AND DISCUSSION

Determination of the effect of the preparation with nanoparticles on the yield of basic seed potatoes showed that on average for 2021-2023 treatment of planting material and plantations according to the scheme: seed treatment with 300 ml/ha + plant treatment with 200 ml/ha during vegetation (variant 2), the yield of seed potatoes of Myroslava variety increased by 2.7 t/ha or 6.94% (at NIR_{05} value of 1.24-1.4 t/ha), and by 2.6 t/ha or 6.9% for Fotyniia variety (at NIR_{05} value of 1.13-1.45 t/ha) (Table 2). Spraying of planting material and vegetative plants with NP Ni did not contribute to the growth of seed potato yields of Myroslava and Fotyniia varieties. The treatment of basic seed potatoes with the product and the use of potato tops desiccation on average for three growing seasons, 2021-2023, increased the yield of Myroslava variety by 2.5 t/ha or 6.5%.

A. Vasylchenko and S. Derevianko (2022) also indicated that the "preparation with nanoparticles" has antioxidant and protective activity and contributes to the growth of crop productivity. The use of the NP Se+I composition had a positive effect on the marketability of tubers and potato yield. W.A. Al-Selwey *et al.* (2023) determined that the use of ZnO and SiO_2 nanoparticles improved the biochemical properties of potato tubers, contributed to increased plant resistance to diseases, improved growth and development, and increased productivity and quality of potatoes under moisture deficit conditions. The use of mineral oil against the background of treatments with preparation with nanoparticles and desiccation of potato tops contributed to an increase in yield by 3.3 (9.5%) t/ha in the Myroslava potato variety (with a NIR_{05} value of 1.94-2.01 t/ha). In the Fotyniia variety, this variant did not show an increase in yield. The use of mineral oil against the background of treatments of planting material and plants during the growing season with NP Ni provided an increase in the yield of potato variety Myroslava in 2023 by 2.0 t/ha, while this effect was not detected in the potato variety Fotyniia.

Table 2*. Effect of the use of plant protection system elements against virus infections of basic seed potatoes on yield, 2021-2023*

Variant number	Experiment variants	2021			2022			2023			2021-2023		
		Yield, t/ha	Increase		Yield, t/ha	Increase		Yield, t/ha	Increase		Yield, t/ha	Increase	
			t/ha	%		t/ha	%		t/ha	%		t/ha	%
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Myroslava variety													
1.	Control 1. Processing with Celeste® Top	41.1	-	-	41.7	-	-	34.1	-	-	38.9	-	-
2.	Processing with Avatar-2 Protection	43.4	2.3	5.6	44.7	3.0	7.2	36.6	2.5	7.3	41.6	2.7	6.94
3.	Ni+ processing with Celeste® Top	41.3	-	-	41.9	-	-	35.0	-	-	39.4	-	-
	HIP_{05}	**-**	**1.24**		**-**	**1.40**		**-**	**1.29**		**-**	**-**	

Table 2. Continued

Variant number	Experiment variants	2021			2022			2023			2021-2023		
		Yield, t/ha	Increase		Yield, t/ha	Increase		Yield, t/ha	Increase		Yield, t/ha	Increase	
			t/ha	%		t/ha	%		t/ha	%		t/ha	%
1	2	3	4	5	6	7	8	9	10	11	12	13	14
	S_x%	-	0.9		-	0.9		-	1.1		-	-	
4.	Control 2. Processing with Celeste® Top alongside desiccation	36.8	-	-	40.4	-	-	30.0	-	-	35.7	-	-
5.	Processing with Avatar-2 Protection alongside desiccation	40.2	3.4	9.2	42.3	-	-	32.0	2.0	6.7	38.2	2.5	6.5
6.	Ni treatment + Celeste Top® alongside desiccation	36.0	-	-	40.1	-	-	28.0	-	-	34.7	-	-
	HIP$_{05}$	**-**	**1.30**		**-**	**2.55**		**-**	**1.95**		**-**	**-**	
	S_x%	-	1.0		-	1.8		-			-	-	
7.	Control 3. Treatment with Celeste® Top alongside desiccation	36.8	-	-	37.9	-	-	29.1	-	-	34.6	-	-
8.	Processing with Avatar-2 Protection alongside mineral oil and desiccation	40.1	3.3	8.9	40.5	2.6	6.9	33.0	3.9	13.4	37.9	3.3	9.5
9	Ni treatment + Celeste Top® alongside mineral oil and desiccation	36.7	-	-	42.1	4.2	11.1	31.0	1.9	6.5	36.6	2.0	5.8
	HIP$_{05}$	**-**	**2.01**		**-**	**1.94**		**-**	**1.95**		**-**	**-**	
	S_x%	-	1.5		-	1.4		-	1.9		-	-	
	Variety Photinia												
1.	Control 1. Processing with Celeste® Top	33.3	-	-	40.6	-	-	38.7	-	-	37.5	-	-
2.	Processing with Avatar-2 Protection	36.8	3.5	10.5	43.3	2.7	6.7	40.1	-	-	40.1	2.6	6.9
3.	Ni+ processing with Celeste® Top	33.8	-	-	39.6	-	-	39.5	-	-	37.6	1.4	3.7
	HIP$_{05}$	**-**	1.13		**-**	1.45		**-**	1.20		**-**	**-**	
	S_x%	-	0.9		-	1.0		-	1.0		-	-	
4.	Control 2. Processing with Celeste® Top alongside desiccation	28.6	-	-	38.3	-	-	28.3	-	-	31.7	-	-
5.	Processing with Avatar-2 Protection alongside desiccation	31.4	2.8	9.8	41.4	2.6	6.8-	27.2	-	-	33.3	1.6	5.0
6.	Ni treatment + Celeste Top® alongside desiccation	28.7	-	-	39.3	-	-	30.2	2.1	7.4	32.7	1.0	3.2
	HIP$_{05}$	**-**	2.30		**-**	2.07		**-**	1.39		**-**	**-**	
	S_x%	-	2.3		-	1.5		-	1.7		-	-	
7.	Control 3. Treatment with Celeste® Top alongside desiccation	28.6	-	-	42.6	-	-	29.7	-	-	33.6	-	-
8.	Processing with Avatar-2 Protection alongside mineral oil and desiccation	30.6	2.0	7.0	42.1	-	-	29.1	-	-	33.9	0.3	0.9
9	Ni treatment + Celeste Top® alongside mineral oil and desiccation	28.7	-	-	41.7	-	-	28.2	-	-	32.9	-	-
	HIP$_{05}$	**-**	**2.42**		**-**	**1.13**		**-**	**1.42**		**-**	**-**	
	S_x%	-	2.4		-	0.8		-	1.7		-	-	

Source: compiled by the author

In studies on the action of NP Se+I and preparation with nanoparticles, S. Derevianko and A. Vasylchenko (2020) determined the most effective composition for the control of infectious diseases in potatoes. The study by S. Liu *et al.* (2024) on the antiviral properties of NP of copper oxide (CuONPs) using orange peel extract showed effective control of *tobacco mosaic virus* (TMV) infection both *in vitro* and *in vivo*. L. Cai *et al.* (2020) highlighted antiviral activity against the Tobacco mosaic virus of NP Fe_3O_4. Studies conducted in 2021-2023 determined that the use of the drug and NP Ni for the treatment of planting tubers and plantations reduced the manifestation of symptoms of viral diseases on vegetative potato plants (Table 3).

***Table 3**. Influence of plant protection system elements on the defeat of basic seed potatoes by viral diseases (by symptoms), 2021-2023, %*

Variant number	Experiment variants	Mottling	Mosaic leaf curl	Wrinkled and striped mosaics	Total
1	2	3	4	5	6
	Myroslava variety				
1.	Control of processing with Celeste® Top	3.18	1.17	0.17	4.51
2.	Processing with Avatar-2 Protection	1.26	0.41	0	1.68
3.	Ni+ processing with Celeste® Top	2.12	0.99	0	3.11
4.	Control of processing with Celeste® Top alongside desiccation	2.09	0.53	0	2.62
5.	Treatment with Avatar-2 protection alongside tops removal	1.14	0.26	0	1.4
6.	Ni treatment with Celeste® Top alongside tops removal	1.57	0.42	0	1.99
7.	Control of treatment with Celeste® Top alongside tops removal	0.59	0.33	0	0.93
8.	Treatment with Avatar-2 protection alongside Celeste® Top and mineral oil with tops removal	0.75	0.25	0	1
9.	Ni treatment with Celeste® Top alongside mineral oil and tops removal	0.97	0.3	0	1.27
	HIP_{05}	**0.90**	**0.36**	**0.05**	**1.31**
	S_x%	0.30	0.12	0.02	0.43
	Fotyniia variety				
1.	Control of processing with Celeste® Top	3.18	1.37	0.17	4.71
2.	Processing with Avatar-2 Protection	1.61	0.5	0	2.11
3.	Ni+ processing with Celeste® Top	2.34	0.73	0	3.08
4.	Control of processing with Celeste® Top alongside desiccation	1.67	0.7	0	2.37
5.	Treatment with Avatar-2 protection alongside tops removal	1.14	0.4	0	1.54
6.	Ni treatment with Celeste® Top alongside tops removal	1.41	0.57	0	1.98
7.	Control of treatment with Celeste® Top alongside tops removal	0.56	0.23	0	0.79
8.	Treatment with Avatar-2 protection alongside Celeste® Top and mineral oil with tops removal	0.65	0.27	0	0.92
9.	Ni treatment with Celeste® Top alongside mineral oil and tops removal	0.69	0.23	0	0.92
	HIP_{05}	**0.90**	**0.38**	**0.05**	**1.33**
	S_x%	0.30	0.13	0.02	0.45

***Source:** compiled by the author*

Seed potatoes of the Myroslava variety under treatment of tubers before planting and double spraying of plants with preparation with nanoparticles (variant 2) had a 2.9% reduction in plant damage by viral diseases compared to the control without treatment by visual assessment. In the variety Fotyniia, the reduction of viral diseases was 2.6%, while the damage in the control was 4.7%. Reduction of plant damage by mosaic curl of potato leaves (causative agent – *Potato virus M* (PVM)) in Myroslava variety was 0.7%, in Fotyniia variety – 0.8%, by leaf spot disease (causative agent – *Potato virus S* (PVS)) – by 2.2% and 1.6%, respectively, by varieties. Symptoms of potato plant damage by wrinkled and striped mosaic (causative agent – *Potato virus Y*) were observed in the control variant without treatments – 0.3% of plants in the Myroslava variety and 0.2% of plants in the Fotyniia variety. The use of a product based on Ni NF reduced the manifestation of symptoms of viral diseases by 1.5% in the Myroslava potato variety and by 1.7% in the Fotyniia potato variety; when using potato tops desiccation – by 0.7% and 0.5%, respectively. Desiccation of tops (variant 4) contributed to a 1.7% reduction in potato virus infection in the Myroslava variety and 1.5% in the Fotyniia variety.

The combination of tops desiccation with nanoparticle treatment (variant 5) reduced the damage of the Myroslava variety by virus diseases by 3.1%, the Fotyniia variety – by 3.2%, including mosaic curl by 2.0% and 0.9% respectively, with the disease affecting 1.1% and 1.3% of plants in the control, respectively, by varieties. The use of mineral oil (variant 7) contributed to a decrease in plant damage by viral diseases compared to the control with desiccation of the aboveground mass of plants in the Myroslava variety by 1.8%, and in the Fotyniia variety – by 1.9%. The complex effect of the preparation, tops desiccation, and oil treatment of plants (variant 8) provided a 3.5% reduction in seed potato virus disease damage in Myroslava and 4.0% in Fotyniia. N.I. Helmy *et al.* (2023) determined that NPs are effective in combating plant viruses. The comparison of curcumin (Cur) and curcumin NPs (Cur NPs) as methods of protection against potato virus Y NTN (PVYNTN) infection determined that plants treated with Cur NPs+V (10 mg/ml) had the highest percentage of reduction in severe viral disease (98%), therefore Cu NPs have the potential of a low-cost, highly effective means of controlling potato viruses and are an alternative to traditional PVY control technologies.

The results of ELISA diagnostics of seed potatoes in the post-harvest period in 2023 (Table 4) showed that the treatment of planting material and vegetative potato plants with preparation with nanoparticles contributed to a decrease in the damage to seed potatoes by PVY. The reduction in the level of PVY damage to potato plants relative to the control variant of Myroslava and Fotyniia varieties was 0.5%, while the control indicator was 1.0%. Treatment of plants with the preparation and desiccation of the aboveground part of plants during three growing seasons (variant 6) ensured the absence of infected potato plants with PVY, while in the control variant, 1.0% of diseased plants were found. Research conducted by M.A. Shah *et al.* (2021) found that mineral oils reduce the spread of PVY by more than 50% compared to untreated controls. M. Kamlesh *et al.* (2020) and V. Rakesh *et al.* (2024) also confirmed that mineral oils in combination with insecticidal treatments provided a high level of efficiency (over 50%) in protecting seed potatoes from PVY infection in the field. T.D.B. MacKenzie *et al.* (2020) highlighted the importance of mineral oil treatments of seed potato plantations in maintaining seed quality. The use of mineral oil treatments of seed potato plantations (variant 7, 8, 9) against the background of insecticide treatments ensured that the varieties Myroslava and Fotyniia did not have PVY infection.

***Table 4**. Dependence of infection of basic seed potatoes with Potato virus Y on the use of plant protection system elements,%, 2023*

Variant number	Experiment variants	PVY
	Myroslava variety	
1.	Control1 Celeste® Top	1.0
2.	Avatar-2 Protection	0.5
3.	NP Ni + Celeste® Top	1.0
4.	Control 2. Celeste® Top + tops removal	0.5
5.	Avatar-2 Protection + tops removal	0
6.	NP Ni with Celeste® Top alongside tops removal	0.5
7.	Control 3. Celeste® Top alongside mineral oil and tops removal	0
8.	Avatar-2 protection alongside Celeste® Top and mineral oil with tops removal	0
9.	NP N_i treatment with Celeste® Top alongside mineral oil and tops removal	0
	Fotyniia variety	
1.	Control1 Celeste® Top	1.0
2.	Avatar-2 Protection	0.5
3.	NP Ni + Celeste® Top	1.0
4.	Control 2. Celeste® Top + tops removal	0.5
5.	Avatar-2 Protection + tops removal	0
6.	NP Ni with Celeste® Top alongside tops removal	0.5
7.	Control 3. Celeste® Top alongside mineral oil and tops removal	0
8.	Avatar-2 protection alongside Celeste® Top and mineral oil with tops removal	0
9.	NP N_i treatment with Celeste® Top alongside mineral oil and tops removal	0

***Source:** compiled by the author*

As a result of the research, methods were developed to reduce the infection of seed potatoes with viral pathogens in the agroecological conditions of the Southern Polissia zone of Ukraine using a nanoparticle-based preparation, Ni NPs, insecticidal plant treatments in combination with "mineral oil" and tops removal.

CONCLUSIONS

The use of early desiccation and preparation with nanoparticles in 2021-2023 reduced the damage to plants of the Myroslava variety by virus diseases by 2.9%, in the Fotyniia variety the reduction of virus disease damage was 2.6%, while the value in the control without treatment was 4.7%. The use of mineral oil reduced the manifestation of symptoms of viral diseases on potato plants compared to the control without desiccation treatment in the Fotyniia variety by 1.9% and in the Miroslava variety by 1.8%. The combined effect of the preparation, top desiccation and oil treatment of plants ensured a 3.5% reduction in the manifestation of symptoms of viral diseases in the Myroslava potato variety and a 4.0% reduction in the Fotyniia variety. Symptoms of potato plants affected by wrinkled and striped mosaics (*Potato virus Y* pathogen) were observed in the control variant without treatments – 0.3% of plants in the Myroslava variety and 0.2% of plants in the Fotyniia variety.

ELISA diagnostics of plants grown from seed potato tubers showed that treatment of vegetative plants with nanoparticle preparation reduced PVY damage in Myroslava and Fotyniia varieties by 0.5%, while the damage in the control plants of both varieties was 1.0%. The treatment of plants with the product, desiccation of tops, and treatment of plants with mineral oil during three growing seasons ensured the absence of infected PVY potato plants, while 1.0% of diseased plants were found in the control variant. Elements of the plant protection system for basic seed potatoes against viral infections were developed using a biological preparation based on Ni nanoparticles, with the application of mineral oil in plantations in combination with insecticides and top removal. The proposed measures had a positive effect on the yield of basic seed potatoes of Myroslava and Fotyniiaa varieties in the South of Polissia of Ukraine. The average yield increase during the research period for the application of the preparation with nanoparticles was 2.7 t/ha for the Myroslava seed potato variety and 2.6 t/ha for the Fotyniia variety. The use of Ni NPs did not contribute to the growth of the yield of potato varieties Miroslava and Fotyniia.

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CONFLICT OF INTEREST

None.

REFERENCES

[1] Al-Selwey, W.A., Alsadon, A.A., Alenazi, M.M., Tarroum, M., Ibrahim, A.A., Ahmad, A., Osman, M., & Seleiman, M.F. (2023). Morphological and biochemical response of potatoes to exogenous application of ZnO and SiO_2 nanoparticles in a water deficit environment. *Horticulturae*, 9(8), article number 883. doi: 10.3390/horticulturae9080883.

[2] Baliota, G.V., & Athanassiou, C.G. (2023). Use of paraffin oils in agriculture and beyond: Back to the future. *Environmental Science and Pollution Research*, 30, 2392-2405. doi: 10.1007/s11356-022-24059-5.

[3] Bondarchuk, A., Vyshnevska, O., Dmytrenko, V., & Riazantsev, M. (2020). Results of vectors monitoring, measures to combat viral diseases of potatoes in the area of the Ukraine's Polissia. *Foothill and Mountain Agriculture and Stockbreeding*, 67(2), 8-28. doi: 10.32636/01308521.2020-(67)-2-1.

[4] Bondarchuk, A.A., Koltunov, V.A., Oliynyk, T.M., Furdyga, M.M., Vishnevska, O.V., Osypchuk, A.A., Kupriyanova, T.M., & Zakharchuk, N.A. (2019). *Potatoes: Research methodology*. Vinnytsia: "Nilan-LTD".

[5] Cai, L., Cai, L., Jia, H., Liu, C., Wang, D., & Sun, X. (2020). Foliar exposure of Fe_3O_4 nanoparticles on *Nicotiana benthamiana*: Evidence for nanoparticles uptake, plant growth promoter and defense response elicitor against plant virus. *Journal of Hazardous Materials*, 393, article number 122415. doi: 10.1016/j.jhazmat.2020.122415.

[6] Convention on Biological Diversity. (1992, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_030#Text.

[7] Convention on International Trade in Endangered Species of Wild Fauna and Flora. (1979, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_129#Text.

[8] Demchuk, I., Reshotko, L., Volkova I., & Vyshnevska, O. (2024). Distribution of PVY potatoes in the Chernihiv and Kyiv regions of Ukraine. *Bulletin of Agricultural Science*, 102(3), 21-27. doi: 10.31073/agrovisnyk202403-03.

[9] Derevianko, S., & Vasylchenko, A. (2020). Reproduction of the strain of bacteria Bacillus Subtilis IMV B-7023 in the presence of nanomaterials with different chemical composition. In *Innovative scientific researches: European development trends and regional aspect* (pp. 113-135). Riga: Baltija Publishing. doi: 10.30525/978-9934-588-38-9-56.

[10] Furdyha, M.M., Vyshnevska, O.V., Oliynyk, T.M., Sidliarenko, V.V., Chaikovskyi, V.M., & Chelombitko, A.F. (2024). *Methods determination of sowing qualities and post-harvest evaluation of direct of seed potato progeny*. Vinnytsia: Tvory.

[11] Furdyha, M.M., Vyshnevska, O.V., Oliynyk, T.M., Zakharchuk, N.A., Ryazantsev, M.V., Samoilichenko, O.V., Shmun, S.A., & Dmytrenko, V.P. (2023). *Guidelines for field evaluation of seed potato plantations*. Vinnytsia: Works.

[12] Helmy, N.I., Mahfouze, S.A., Othman, B.A.S., El-Dougdoug, K.A.F., & Faiesal, A. (2023). Enhance potato resistance to Potato virus Y^{NTN} using curcumin nanoparticles. *Acta Fytotechnica et Zootechnica*, 26(3), 294-304. doi: 10.15414/afz.2023.26.03.294-304.

[13] Jones, R.A.C. (2021). Global plant virus disease pandemics and epidemics. *Plants*, 10(2), article number 233. doi: 10.3390/plants10020233.

[14] Kamlesh, M., Raghavendra, K.V., & Kumar, M. (2020). Vector management strategies against *Bemisia tabaci* (Gennadius) transmitting potato apical leaf curl virus in seed potatoes. *Potato Research*, 64, 167-176. doi: 10.1007/s11540-020-09470-0.

[15] Kreuze, J.F., Souza-Dias, J.A.C., Jeevalatha, A., Figueira, A.R., Valkonen, J.P.T., & Jones, R.A.C. (2020). Viral diseases in potato. In H. Campos & O. Ortiz (Eds.), *The potato crop*. (pp. 389-430). Cham: Springer. doi: 10.1007/978-3-030-28683-5_11.
[16] Liu, S., Tian, W., Liu, Z., Wei, X., Yuan, K., Du, W., Chen, S., Chen, S., Zhou D., & Cai L. (2024). Biosynthesis of cupric oxide nanoparticles: Its antiviral activities against TMV by directly destroying virion and inducing plant resistance. *Phytopathology Research*, 6, article number 30. doi: 10.1186/s42483-024-00250-z.
[17] MacKenzie, T.D.B., Nie, X., & Singh, M. (2020). Epidemiology and management of potato virus Y. In *Emerging trends in plant pathology*. (pp. 113-140). Singapore: Springer. doi: 10.1007/978-981-15-6275-4_6.
[18] MacKenzie, T.D.B., Nie, X., & Singh, M. (2022). Comparison of mineral oil, insecticidal, and biopesticide spraying regimes for reducing spread of three *potato virus Y* strains in potato crops. *Plant Disease*, 106(3), 891-900. doi: 10.1094/PDIS-06-21-1213-RE.
[19] Mondal, S., Wintermantel, W.M., & Gray S.M. (2023). Infection dynamics of potato virus Y isolate combinations in three potato cultivars. *Plant Disease*, 107(1), 157-166. doi: 10.1094/PDIS-09-21-1980-RE.
[20] Rakesh, V., Rajesh, V., Jeevalatha, A., & Ghosh, A. (2024). Exploring the relationship of potato viruses with aphid and whitefly vectors. In *Approaches for potato crop improvement and stress management* (pp. 249-287). Singapore: Springer. doi: 10.1007/978-981-97-1223-6_9.
[21] Rashwan, B., Abd Elhamed, R., & Albakry, A. (2023). Effect of zinc oxide nanoparticles on growth, chemical composition and yield of potato (*Solanum tuberosum* L.). *Journal of Soil Sciences and Agricultural Engineering*, 14(3), 65-71. doi: 10.21608/jssae.2023.182582.1126.
[22] Rolot, J.L., Seutin, H., & Deveux, L. (2021). Assessment of treatments to control the spread of PVY in seed potato crops: Results obtained in Belgium through a multi-year trial. *Potato Research*, 64, 435-458. doi: 10.1007/s11540-020-09485-7.
[23] Shah, M.,A., Naga, K.C., Subhash, S., Sharma, S., & Kumar, R. (2021). Use of petroleum-derived spray oils for the management of vector-virus complex in potato. *Potato Research*, 65, 1-19. doi: 10.1007/s11540-021-09505-0.
[24] Talebi, S.M., & Ghorbanpour, M. (2023). Nanoparticles treatment ameliorate the side effects of stresses in plants. In *Plant stress mitigator* (pp. 469-478.). Cambridge: Academic Press. doi: 10.1016/B978-0-323-89871-3.00010-0.
[25] Torrance, L., & Talianksy, M.E. (2020). Potato virus Y emergence and evolution from the andes of South America to become a major destructive pathogen of potato and other solanaceous crops worldwide. *Viruses*, 12(12), article number 1430. doi: 10.3390/v12121430.
[26] Vasylchenko, A., & Derevianko, S. (2022). Use of nanoparticles and nanotechnologies in potato growing. *Bulletin of Agricultural Science*, 100(9), 43-54. doi: 10.31073/agrovisnyk202209-05.
[27] Vushnevska, O., Dmytrenko, V., Zakharchuk N., & Oliinyk, T. (2021). Productivity and viral diseases of seed potatoes depending on the period of potato desiccation. *EUREKA: Life Sciences*, 5, 26-34. doi: 10.21303/2504-5695.2021.002067.

Захист насіннєвої картоплі від ураження вірусними інфекціями в польових умовах Полісся України

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Анотація. Вірусні хвороби становлять значну проблему для насінництва картоплі, тому для забезпечення високих якісних характеристик насіннєвого матеріалу важливими є дослідження щодо розробки нових методів їх контролю. Мета досліджень полягала у визначенні ефективності комплексного застосування елементів системи захисту насаджень базової насіннєвої картоплі від вірусних хвороб за використання мінеральних олій, видалення бадилля та біологічних препаратів на основі наночастинок в умовах Півдня Полісся України. Встановлено, що обробка садивних бульб картоплі та обприскування рослин під час вегетації нанопрепаратом біологічного походження підвищували рівень урожайності насіннєвої картоплі сорту Мирослава відносно контролю без обробок на 2,7 т/га або 6,94 %, сорту Фотинія – на 2,6 т/га або 6,9 %. Застосування десикації картоплиння, обробок та мінеральної олії забезпечило приріст урожайності сорту Мирослава на 3,3 т/га або на 9,5 %. Використання десикації картоплиння та обробок картоплі впродовж трьох вегетаційних сезонів за результатами візуального методу оцінювання насаджень сприяло зниженню ураження рослин сорту картоплі Мирослава вірусними хворобами на 2,9 %, сорту Фотинія – на 2,6 %, за ураження рослин на контролі відповідно у сортів 4,5 та 4,7 %. Результати імуноферментної діагностики картоплі у післязбиральний період показали, що обробки вегетуючих рослин картоплі нанопрепаратом сприяли зниженню зараження насіннєвої картоплі *Potato virus Y* (PVY) на 0,5 %, за ураження рослин вірусною інфекцією PVY на контролі без обробок 1,0 %. За результатами досліджень запропоновано елементи системи комплексного застосування багатокомпонентного нанопрепарату біологічного походження, обприскувань насаджень інсектицидами та мінеральною олією та десикації картоплиння для боротьби з вірусними хворобами добазової, базової та сертифікованої насіннєвої картоплі

Ключові слова: урожайність; вірусні хвороби; інфекція *Potato virus Y*; препарати на основі наночастинок; мінеральна олія
