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Research Article

Effectiveness of the Nematicidal Preparation Against the Potato Nematode Complex

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Abstract

Summary: Potato cultivation is a crucial area in crop production, especially in the Southern Steppe of Ukraine, where agroecological conditions require effective plant protection strategies. Yield is influenced by numerous factors, one of which is infestation by phytonematodes. This is particularly relevant under irrigated farming conditions, which promote the development of harmful nematode species. The article presents the results of testing a nematicidal preparation based on the predatory fungus Arthrobotrys oligospora against a complex of potato nematodes under model vegetative experiment conditions. This approach makes it possible to evaluate the potential efficacy of the product before large-scale field application. A reduction was observed in the total number of phytophagous nematodes (Paratylenchus nanus, Pratylenchus pratensis), mycetophagous nematodes (Aphelenchoides asterocaudatus, A. limberi, Aphelenchus avenae), and saprophagous nematodes (Aporcelaimellus obtusicaudatus, Chiloplacus symmetricus, Eucephalobus oxiuroides, Panagrolaimus rigidus), as well as in the invasion intensity of dominant endophytic species. Double treatment (tuber soaking and vegetative spraying) resulted in the complete absence of Pratylenchus pratensis in tubers. The preparation did not significantly affect tuber yield structure, although a trend toward increased tuber weight was noted compared to the infected control. These findings are promising for the development of biological nematicidal control methods. The article presents the results of examining a nematicidal preparation based on the predatory fungus Arthrobotrys oligospora against a complex of potato nematodes under vegetation experiment conditions. The preparation reduced the overall nematode population and partially limited the activity of dominant endophytic species Pratylenchus pratensis and Paratylenchus nanus.

Keywords

Potato, Nematodes, Nematophagin

1. Introduction

In the arid climate conditions of the northwestern Black Sea region, potatoes are mostly cultivated in private households for personal consumption. Ultra-early varieties are commonly used to harvest the crop before the onset of drought.

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Long-term storage of potatoes is generally not practiced. During cultivation, potato tubers are often affected by dry rot, which can partly be caused by nematode infestation. Nematodes directly damage plants, may provoke fungal and bacterial diseases, and can also transmit viral infections.

Previous studies have shown that in the Odesa region, the potato nematode complex includes 13 species: five phytoparasitic nematodes (*Pratylenchus pratensis* (de Man 1889) Filipjev 1936, *Paratylenchus nanus* Cobb, 1923, *Ditylenchus dipsaci* (Kühn, 1857), *Tylenchorhynchus dubius* (Bütschli, 1873) Filipjev, 1936, *Helicotylenchus dihystera* (Cobb, 1893) Sher, 1961; the potato stem nematode was not detected), four mycophagous nematodes (*Aphelenchus avenae* Bastian, 1965; *Aphelenchoides asterocaudatus* Das, 1967; *Aphelenchoides limberi* Steiner, 1936; *Aglenchus agricola* (De Man, 1921) Andrassy, 1954), and four saprobiotic species (*Aporcelaimellus* (Eudorylaimus) obtusicaudatus (Bastian, 1865) Heyns, 1965 - omnivorous; *Eucephalobus oxiuroides* (De Man, 1880) Steiner, 1936; *Mesorhabditis monohystera* (Bütschli, 1873) Dougherty, 1955; *Panagrolaimus rigidus* (Schneider, 1866) Thorne, 1937).

The dominant species are the polyphagous *Pratylenchus pratensis* and *Paratylenchus nanus* [1].

To regulate nematode populations, chemical preparations are mostly used; however, in recent years, increasing attention has been paid to biological methods of population control [2].

A promising approach in this direction is the use of bacteria (*Bacillus thuringiensis*), whose toxins can be lethal to nematodes; micromycetes (*Trichoderma spp.*) [3], which act as nematode antagonists and can suppress their development; and entomopathogenic nematodes (*Steinernema* and *Heterorhabditis*), which release symbiotic bacteria inside the pest's body, leading to its death. However, the most promising method is the use of predatory fungi [4], which actively destroy nematodes.

2. Objective

The aim of the study was to determine the effect of the preparation Nematofagin, based on the predatory fungus Arthrobotrys oligospora, on the potato nematode complex under the conditions of the Odesa region.

3. Materials and Methods

The evaluation of the preparation's effectiveness was carried out under the conditions of a vegetation experiment, which included several stages.

Preparation and characterization of invasive material. Potatoes showing signs of dry rot damage were collected from a private household (village of Mykolaivska, Odesa region - 45°54'02"N 30°13'07"E). The nematode population and species composition were analyzed. The average nematode population in damaged tubers was 225 specimens per 10 g, with a range from 0 to 2430 individuals. The nematode complex consisted of six species: Phytophagous nematodes - Paratylenchus nanus Cobb, 1923 and Pratylenchus pratensis (de Man 1889) Filipjev 1936; Mycetophagous nematodes - Aphelenchoides asterocaudatus Das, 1967, Aphelenchoides limberi Steiner, 1936, Aphelenchus avenae Bastian, 1965; Saprophagous nematodes - Panagrolaimus rigidus (Schneider, 1866).

Pratylenchus pratensis (family Pratylenchidae) is described by researchers as a cosmopolitan species that causes significant damage to cereal and vegetable crops [5]. It inhabits plant roots, moves within the root cortex, and can migrate from one root to another. Its full development cycle lasts 6-8 weeks, with 5-6 generations per year. A general symptom of plant damage is stunted growth. In annual cultivated plants, additional symptoms include yellowing of the leaves and their tips, and in some cases, plant death. The roots of affected plants often exhibit reddish or black necrotic spots. The critical population threshold at which damage becomes evident in potatoes is 100 individuals per 100 cm^3 of soil. Leguminous crops (peas, faba beans, common beans) are less favorable hosts. The broad host range and ability of Pratylenchus spp. to accumulate in the soil provide grounds to consider them as one of the factors contributing to “soil fatigue” (Vasiliev, 1987). Pratylenchus pratensis is an endoparasitic species widely distributed in the Odesa region [1], which justified the selection of these samples for the experiment.

Substrate and Container Preparation. Plastic containers with a volume of 3 liters were used. The substrate was a mixture of soil and sand in a 2:1 ratio, which was thoroughly dried beforehand.

Experimental Procedure. Given that stem nematodes are known to migrate from soil into plants and vice versa [6], the infestation was performed through the soil. The invasive material was crushed into fragments approximately 1 cm^3 in size and placed into each planting hole at a rate of 10 g per hole for all experimental treatments, except for the untreated control. Experimental Treatments: untreated control (no infestation); infested control (no treatment); pre-planting tuber soaking in a 5% solution of Nematofagin for 12 hours; foliar treatment of potato plants during vegetation stages (stem elongation, budding, flowering) with a 3% solution of Nematofagin; combination of tuber soaking and foliar treatment during vegetation.

Pre-sprouted tubers of the potato variety Slavuta were used in the experiment. The experiment was laid out with eight replications.

The containers were kept indoors at a temperature of 18-25°C and under natural daylight conditions with illumination ranging from 40,000 to 70,000 lux (Figures 1, 2). Observations continued until harvest. Yield was assessed individually for each plant (Figure 3), including the number of tubers, their total weight, the number of stems, and the height of the main stem. Tubers, roots, and the above-ground parts (10 cm above the soil surface) were analyzed for the presence of nematodes.

Nematode extraction was performed using the Osmolovsky method. After extraction, the extent of infestation (percentage of infected plants) and intensity of infestation (total number of nematodes per 10 g of plant material) were determined. Temporary microscope slides were prepared for species identification.

Figure 1. *Condition of experimental plants at the early development stage (April 19, 2024).*

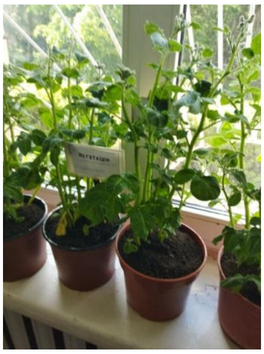

Figure 2. *Onset of flowering in experimental plants (May 14, 2024).*

To assess the residual effect of the preparation and the impact of remaining nematode populations on new planting material, uninfected potato tubers were planted in previously used containers (where nematode infestation had occurred) five months after the initial harvest. Two months later, samples of stems, roots, and both old and newly formed tubers were collected to detect nematodes potentially transferred from the soil into the cultivated plants.

Statistical analysis of the experimental data was conducted using standard methods accepted in crop science, with the aid of STATISTICA 6.0, STATGRAF, and Microsoft Office Excel.

Figure 3. *Harvest from a single plant (June 15, 2024).*

4. Results

The experiments showed that in the control group, where no inoculation of tubers was applied, no endophytic nematodes were recorded. Only mycetophagous and saprophagous nematodes, which could have been introduced from the surface of the planting material, were observed (Table 1).

Table 1. *Nematode Species Composition.*

№	Species	Invasiv Material	Control	Infected Control	Treatment Methods		
					Soaking	Foliar application	Soaking + foliar application
Phytophages							
1	*Paratylenchus nanus* Cobb, 1923	+	-	T	T	-	-
2	*Pratylenchus pratensis* (de Man 1889) Filipjev 1936	+	-	T	T	T	-
Mycetophages							
3	*Aphelenchoides asterocaudatus* Das, 1967	+	R	-	-	-	-
4	*Aphelenchoides limberi* Steiner, 1936	+	-	-	-	-	-
5	*Aphelenchus avenae* Bastian, 1965	+	R	-	-	-	-
Saprophages							

№	Species	Invasiv Material	Control	Infected Control	Treatment Methods		
					Soaking	Foliar application	Soaking + foliar application
6	*Aporcelaimellus (Eudorylaimus) obtusicaudatus* (Bastian, 1865)	-	R	-	R	S, T	-
7	*Chiloplacus symmetricus* (Thorne, 1925)	-	R	R	-	R	-
8	*Eucephalobus oxiuroides* (De Man, 1880)	-	R	-	-	R	-
9	*Panagrolaimus rigidus* (Schneider, 1866)	+	S, R	R	S, R	S, R	S
	Species	6	6	4	2	7	1
	Notation: S - stems, R - roots, T - tubers						

In the control group without Nematofagin treatment, *Paratylenchus nanus* and *Pratylenchus pratensis* were detected in the tubers, whereas in the treatments with the experimental preparation, these species were found only sporadically. This suggests that the effect of the fungus *Arthrobotrys oligospora* is limited and does not lead to the effective destruction of endophytes.

The overall extent of nematode infestation remained high when the treatment with the preparation was applied during the vegetation period. However, the double treatment (soaking and foliar application during vegetation) resulted in the complete absence of *Pratylenchus pratensis* in the tubers.

The use of the preparation significantly reduced the overall nematode population (Table 2), which was represented by saprophagous species Chiloplacus symmetricus and Eucephalobus oxiuroides. The preparation did not show a significant effect on the structure of the potato yield. However, there was a trend towards an increase in tuber weight with the application of the preparation compared to the infected control (Table 3).

Table 2. *Overall Infestation of Potato by Nematodes - Extensiveness (Ei) and Intensity (Ii, specimens/10 g).*

Options	Stems			Roots			Tubers		
	Ei	Ii, specimens/10g		Ei	Ii, specimens/10g		Ei	Ii, specimens/10g	
	%	Average	Range	%	Average	Range	%	Average	Range
Control	67	2302	33-8600	83	4280	133-1400	17	4	4
Control with infestation	0			0			63	40.2	1 - 141
Treatment with nematophagin									
Soaking	0			0			50	8	0.5 - 13.3
Foliar application	0			0			63	3,8	1,1 - 10.0
Soaking + Foliar application	0			0			0		

Table 3. *Elements of Potato Yield Structure Based on the Results of the Model Vegetation Experiment.*

Experimental Treatment	Number of Stems, units	Height of Main Stem, cm	Number of Tubers per Plant, pcs	Tubers Weight per Plant, g	Weight of 1 Tuber, g
Control	5,7	24,7	4,0	63,8	16,0
Control (Inoculation)	7,0	32,7*	6,0*	78,6	13,1*

Experimental Treatment	Number of Stems, units	Height of Main Stem, cm	Number of Tubers per Plant, pcs	Tubers Weight per Plant, g	Weight of 1 Tuber, g
Pre-planting Soaking	8,8	32,8*	5,4*	76,8	14,2*
Vegetation Period Treatment	5,5	35,1*	5,8*	84,3*	14,5
$LSD_{0,05}$	3,6	5,0	1,1	15,4	1,6

After replanting healthy plants in the soil where infected plants were previously grown, no endophytic nematodes were detected in the roots, stems, or tubers.

5. Discussion

The tests conducted under model vegetation conditions showed that the action of the preparation is aimed at limiting the entire nematode complex, including both their population and species composition. The effect on endophytes was limited and was only observed when the preparation was applied twice during the growing season: soaking the tubers before planting and spraying during the vegetation period.

Previous studies have shown that in laboratory conditions, positive results are observed when testing Nematofagin against the potato stem nematode Ditylenchus destructor Thorne, 1945 [8]. Several authors also note the effectiveness of preparations based on the nematocidal fungus A. oligospora against endophytic nematodes such as Meloidogyne incognita [9]. The effectiveness of Nematofagin was reported to be 50% in laboratory conditions against cyst-forming nematodes Globodera pallida [10] and 51.6% against Ditylenchus destructor in field conditions [11]. Therefore, further in-depth studies on the action of A. oligospora on endophytic nematodes, especially the dominant species Paratylenchus nanus and Pratylenchus pratensis, as well as their distribution in the soils of the Odessa region, are needed.

Several authors have established that the use of A. oligospora not only helps in the fight against nematodes but also accelerates plant growth, improves the nutritional value of tomato fruits, and promotes overall plant growth [9, 12]. In our research, we observed a trend toward increased plant biomass (Figure 1) and tuber weight when the Nematofagin preparation was used, which requires further investigation.

6. Conclusions

The Nematofagin preparation based on the predatory fungus *Arthrobotrys oligospora* leads to a reduction in the overall nematode population when growing potatoes in a model vegetation experiment. This includes both phytophagous nematodes (*Paratylenchus nanus*, *Pratylenchus pratensis*), mycophagous nematodes (*Aphelenchoides asterocaudatus*, *Aphelenchoides limberi*, *Aphelenchus avenae*), and saprophagous nematodes (*Aporcelaimellus* (Eudorylaimus) *obtusicaudatus*, *Chiloplacus symmetricus*, *Eucephalobus oxiuroides*, *Panagrolaimus rigidus*). The preparation results in a reduction in the intensity of invasion by the phytophagous nematodes *Paratylenchus nanus* and *Pratylenchus pratensis*, but it does not affect the extent of their invasion.

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Conflicts of Interest

The authors declare no conflicts of interest.

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