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Original article

SENSITIVITY OF PHYTOPATHOGENS OF BERRY CROPS TO NOVOCHIZOL NANOPREPARATIONS *IN VITRO*

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ABSTRACT

Fungal diseases are prevalent among agricultural plants, accounting for more than 80% of all plant diseases. Berry crops, for instance, are susceptible to several fungal infections such as smut, rust, and root rot. In certain regions, these diseases can cause crop losses exceeding 70%. The *in vitro* fungicidal action of Novochizol nanopreparations containing sulfur and copper against pathogenic fungi from the genera *Alternaria* and *Fusarium* was demonstrated. Analysis of the sensitivity of *Alternaria tenuis* and *Fusarium solani* to these nanopreparations revealed that *Alternaria* pathogens showed the highest sensitivity to preparations No. 1, No. 2, No. 3, No. 11, and No. 9. Similarly, *Fusarium solani* was most sensitive to preparations No. 1, No. 2, and No. 3. The sensitivity of *Alternaria tenuis* to Novochizol nanopreparations positively correlates with their fungicidal and fungistatic properties, with a correlation coefficient of 0.845. Conversely, the sensitivity of *Fusarium solani* to the same nanopreparations exhibited a weaker positive correlation, with a coefficient of 0.596.

Keywords: nanopreparation, Novokhizol, phytopathogenic fungi, fungicidal activity, sensitivity, berry crops.

1. INTRODUCTION

Fungal diseases are pervasive among agricultural plants, constituting over 80% of all plant diseases [1]. Recently, regions in the Republic of Kazakhstan and abroad, such as Akmola and Karaganda, have observed significant instances of mass drying in berry crops. These diseases encompass a range of pathogens including smut, rust, and root rot [2]. In affected areas, crop losses due to these diseases can exceed 70% [3].

Pathogenic fungi disrupt the normal development of host plants by penetrating plant tissues and interfering with physiological processes, nutrient absorption, and the release of metabolic products that inhibit cell growth. This disruption leads to tissue death and contributes to a decrease in plant productivity [4]. As plant growth and functioning are compromised, their ability to absorb nutrients, water, and conduct photosynthesis is impaired, ultimately reducing yield or causing plant death [5].

The analysis of mycosis pathogen contamination in berry crops is essential for assessing infection levels and developing effective strategies to prevent disease spread, ensuring the quality and safety of agricultural products. Previous studies have identified phytopathogenic mold fungi affecting berry crops in suburban dacha areas near Astana. These include *Alternaria* spp., isolated from black currants, common raspberries, and garden strawberries, as well as *Fusarium* spp., affecting red currants, black currants, and garden strawberries. Research indicates a 100% contamination rate of four berry crop types (red currants, black currants, common raspberries, and garden strawberries) by various phytopathogenic fungi in suburban Astana [6]. Such high contamination underscores the need for rigorous measures to combat and prevent these pathogens.

Classical fungicidal preparations, commonly known as pesticides, are highly toxic [7]. Mesnage et al. (2014) assessed their toxicity by measuring mitochondrial activity, membrane degradation, and caspase 3/7 activity, finding fungicides to be the most toxic even at concentrations 300-600 times lower than agricultural dilutions. Herbicides and insecticides showed similar toxicity profiles across all cell types, albeit to a lesser extent [8, 9]. Consequently, special precautions are necessary, including observing specific time intervals between treatment and harvesting [8, 9]. Modern systemic fungicides include triazoles and pyrazole carboxamides SDHI (succinate dehydrogenase inhibitors), which represent advancements in reducing environmental and health risks [10].

Colloidal sulfur compounds are well-known for combating fungal diseases and pests in various agricultural crops [11]. Despite their inability to be absorbed directly by plants due to their chemical composition, these preparations are traditionally used in agriculture [12].

Copper-containing compounds are widely recognized as fungicides, primarily employed for the prevention rather than treatment of plant diseases [13]. These preparations are effective against bacteria [14], mold fungi [15], and oomycetes [16]. In organic farming, copper compounds are among the most effective active ingredients combating various pathogens, including anthracnose [17], downy mildew in grapes [18], late blight in potatoes [19], and powdery mildew in numerous other crops [4].

Despite their effectiveness, traditional chemical plant protection products have significant drawbacks such as environmental pollution, ecological damage, and toxicity to humans. Sulfur- or copper-based products, known for their strong fungicidal effects, can also harm beneficial microorganisms, potentially disrupting biological balance [12]. New-generation fungicides are emerging for the treatment of agricultural, industrial, forage, and berry crops. Examples include Abistim

[20], Topsin [21], and Flint [22]. However, these products often contain antibiotics and other aggressive, toxic chemicals [23]. Therefore, there is a critical need to explore new safe, organic, and environmentally friendly alternatives.

Environmental biotechnology has recently focused on developing biological plant protection products based on natural compounds, which are free from the drawbacks associated with traditional chemical products yet remain highly effective. Chitosan, derived from the deacetylation of chitin, one of the most abundant polysaccharides in nature, exemplifies this trend. Its high biological activity, biocompatibility, and safety make chitosan versatile and effective in applications across medicine, industry, and agrobiology [24]. Chitosan possesses several advantageous properties such as biodegradability, hydrophilicity, non-toxicity, high bioavailability, and excellent water permeability. It can also form films, gels, and nanoparticles, further enhancing its utility [25].

Laboratory tests of preparations based on chitin derivatives cross-linked with sulfur and copper have demonstrated that the nanopreparation «Novokhizol», which incorporates chitosan and copper, exhibits potent fungicidal effects against the phytopathogenic fungus Erysiphe spp. The preparation effectively suppresses its growth in vitro, highlighting its potential as a promising tool for protecting apple orchards from powdery mildew [26]. Further investigation into the impact of «Novokhizol» on phytopathogenic pathogens affecting berry crops would be of particular interest.

The aim of the research is to analyze the sensitivity of common phytopathogenic fungi affecting domestic berry crops (red currant, black currant, common raspberry, garden strawberry) to Novochizol nanopreparations containing various combinations of sulfur and copper under in vitro conditions.

2. MATERIAL AND METHODS

The studies were conducted in the microbiology laboratory of the Agricultural Biotechnology Research Platform at the S. Seifullin Kazakh Agrotechnical Research University from 2022 to 2024.

The study focused on plant materials from berry crops (red currant, black currant, common raspberry, garden strawberry) collected from summer cottages in Astana.

The experiment analyzed 15 variants of the Novokhizol nanopreparation provided by scientists from the Siberian Branch of the Russian Academy of Sciences (Novosibirsk) (Table 1).

Provide sufficient details to allow the work to be reproduced by an independent researcher. Methods that are already published should be summarized, and indicated by a reference. Any modifications to existing methods should also be described. For experiments reporting results on animal or human subject research, an ethics approval statement should be included in this section.

The study employed a standard method for sampling plant material, involving the cutting of leaves into 3-4 mm segments followed by sterilization in 70% alcohol for 3 minutes. The sterilized biomaterial was then plated onto Petri dishes containing Chapek Dox Agar nutrient medium and placed in a thermostat at 25-26 °C. Cultivation continued for 3-5 days until colony formation and pronounced sporulation were observed. Microscopic examination was conducted using an Olympus BX43 microscope with a ×40 objective [27].

Isolated pathogens causing phytopathogenic diseases were

Table 1 – List of Novokhisol preparations used in the work.

Preparation No.	Content of active ingredients
1 group of copper-based preparations	
1	Novochizol 1% Cu^{2+} 0.95 mg/ml
2	Novochizol 1,8% Cu^{2+} 0,22 mg/ml, matryoshka, 1 batch
3	Novochizol 1% Cu^{2+} 0.98 mg/ml
4	Novochizol 1,8% Cu^{2+} 0,22 mg/ml, matryoshka, 2 batch
5	Novochizol 1,5% Cu^{2+} 1,95 mg/ml
7	Novochizol 1% Cu^{2+} 1,95 mg/ml
2 group of sulfur-based preparations	
8	Novochizol 1,45% sulfur 20 nm в 0,5%
9	Novochizol 1,9% sulfur 20 nm 0,833 mg/ml
10	Novochizol 1,9% sulfur 140 nm 12,3 mg/ml
11	Novochizo 2% S 140 nm 2 mg/ml
12	Novochizol 2% colloidal sulfur 0,5%
3rd group of preparations – complex	
6	Novochizol 1% Na_2SO_4 1,2 % Cu^{2+} 1,95 mg/ml in the form of sulfate
13	Novochizol 2% colloidal sulfur 0,833 mg/ml matryoshka
4th group control (without sulfur and copper)	
14	Novochizol 2%
15	Chitozan 2,5%

tested against 15 Novokhizol preparations with potential antifungal activity.

The fungicidal activity of nanopreparations was assessed using the classical disk diffusion method (DDM) [28]. Paper disks impregnated with varying concentrations of the antifungal nanopreparation were placed on the surface of agar plates inoculated with daily fungal cultures and then incubated under optimal growth conditions. As the preparation diffused from the disk into the agar, it inhibited fungal growth, resulting in clear zones of inhibition around the disks.

The reliability of the sensitivity results of phytopathogenic fungi to nanopreparations was ensured through different variants of the DDM, including the mega-disc method and groove method [26].

Statistical analysis of the results was performed using standard methods in the Microsoft Office Excel program.

3. RESULTS

An analysis of mycosis pathogen contamination in berry crops from dacha areas of Astana revealed that various types of mold fungi affect these crops (Figures 1 and 2).

The morphological structures of the phytopathogens exhibited distinctive characteristics. The mycelium of *Alternaria* spp. fungi displayed olive or olive-brown coloring, with pear-shaped or lemon-shaped conidia that featured an elongated ‘nose’ of varying length at the upper end. These conidia formed chains that were easily observable under a microscope.

Isolates of the phytopathogenic fungus *Fusarium* spp. exhibited white mycelium with clearly defined conidiophores, along with simple or branched mycelial hyphae. Spindle-sickle-shaped macroconidia, ranging from slightly curved to nearly straight with 3-7 septa, were visible in the field of view. The upper and lower cells of these macroconidia were rounded. Additionally, kidney-shaped microconidia, unicellular and clustered in mucous heads atop long phialides, were observed (Figure 3).

Identification of mycosis pathogens based on cultural and morphological features using microscopy enabled the determination of phytopathogens: *Alternaria tenuis* and *Fusarium solani*. The growth characteristics and colony formation dynamics of these phytopathogens were assessed to establish their growth rates prior to treatment with nanopreparations (Figure 4).

According to the conducted studies, a clear positive correlation was found between the growth of two phytopathogens on all types of berry crops, with a correlation coefficient of 0.993. Micromycetes show more active growth on black currants and less active growth on raspberries. We attribute this to the natural presence of antimicrobial biologically active components in the plant organs.

To assess the sensitivity of phytopathogenic fungi to Novokhizoly nanopreparations and determine their fungicidal properties, daily cultures of phytopathogenic fungi were cultivated. Sterile disks were then inoculated with two isolates of *Alternaria tenuis* from these cultures and treated with nanopreparations. After incubation in a thermostat at 28°C, results were recorded at 24, 48, and 72 hours (Figure 5).

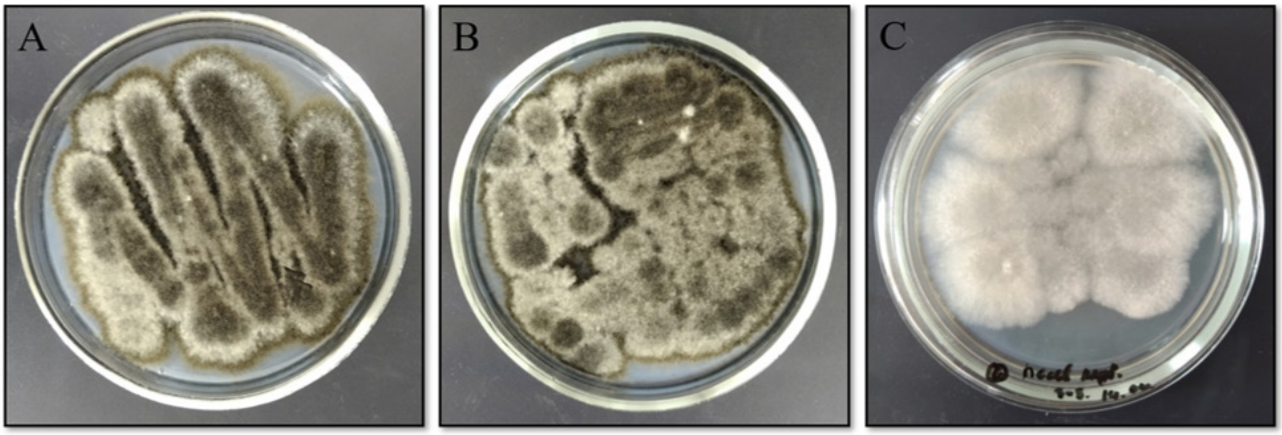

Figure 1 – Pure cultures of *Alternaria* spp. isolated from black currant (A), common raspberry (B), garden strawberry (C).

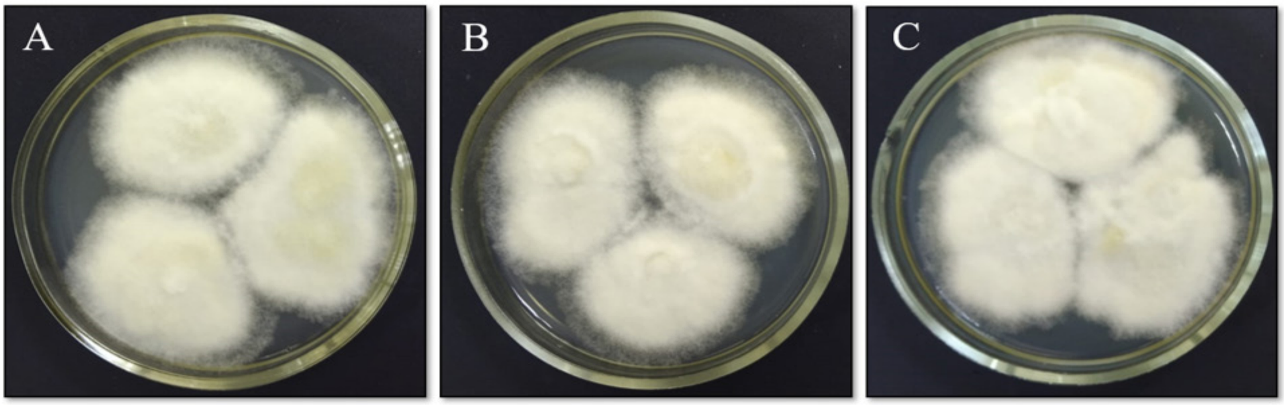

Figure 2 – Pure cultures of *Fusarium* spp. isolated from black currant (A), common raspberry (B), garden strawberry (C).

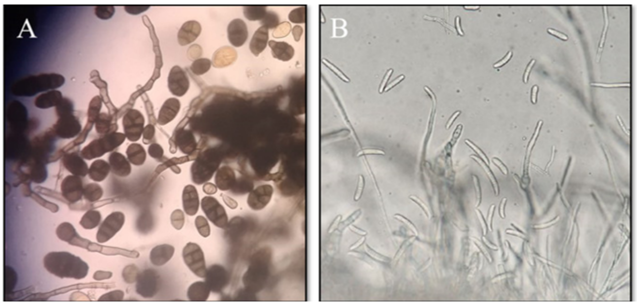

Figure 3 – Morphological structures of phytopathogens:
A - *Alternaria* spp., B - *Fusarium* spp.

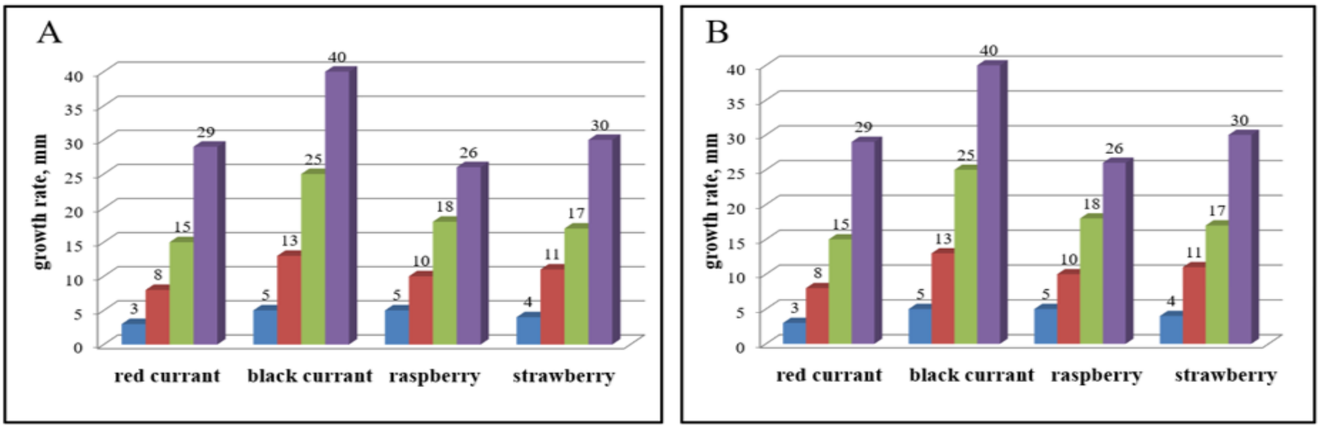

Figure 4 – Diagram of the growth rate of phytopathogenic fungi from berry crops: A – *Alternaria* spp., B – *Fusarium* spp.

Based on the information provided about Figure 5, after 24 hours, a slight growth of phytopathogenic fungi is observed around all disks except No. 1, 2, 3, 4, 5, and 11 for the first isolate of *A. tenuis*. After 48 hours, a zone of no growth of the fungus *A. tenuis* (1st isolate) was observed around the disks with preparations No. 1, 9, and 11. This suggests fungistatic activity of these preparations to which the isolate was sensitive, as evidenced by the delay in fungal growth. After 72 hours, preparations No. 1 and No. 11 continued to exhibit fungistatic activity, indicating their sustained effectiveness against the phytopathogenic fungus. This demonstrates the effectiveness of nanopreparations (preparations No. 1 and No. 11) in inhibiting the growth of *A. tenuis* over the course of 72 hours, highlighting their potential as fungistatic agents.

To confirm the identified fungistatic properties of nanopreparations against phytopathogen isolates from berry crops, we tested a modified disk-diffusion method using mega-disks. The method involves increasing the disk diameter and nanopreparation density per unit area of the nutrient medium, facilitating precise assessment of each nanopreparation's effect with only one disk per Petri dish.

Sterile mega-disks loaded with nanopreparations were placed on daily cultures of *A. tenuis*, one disk per Petri dish,

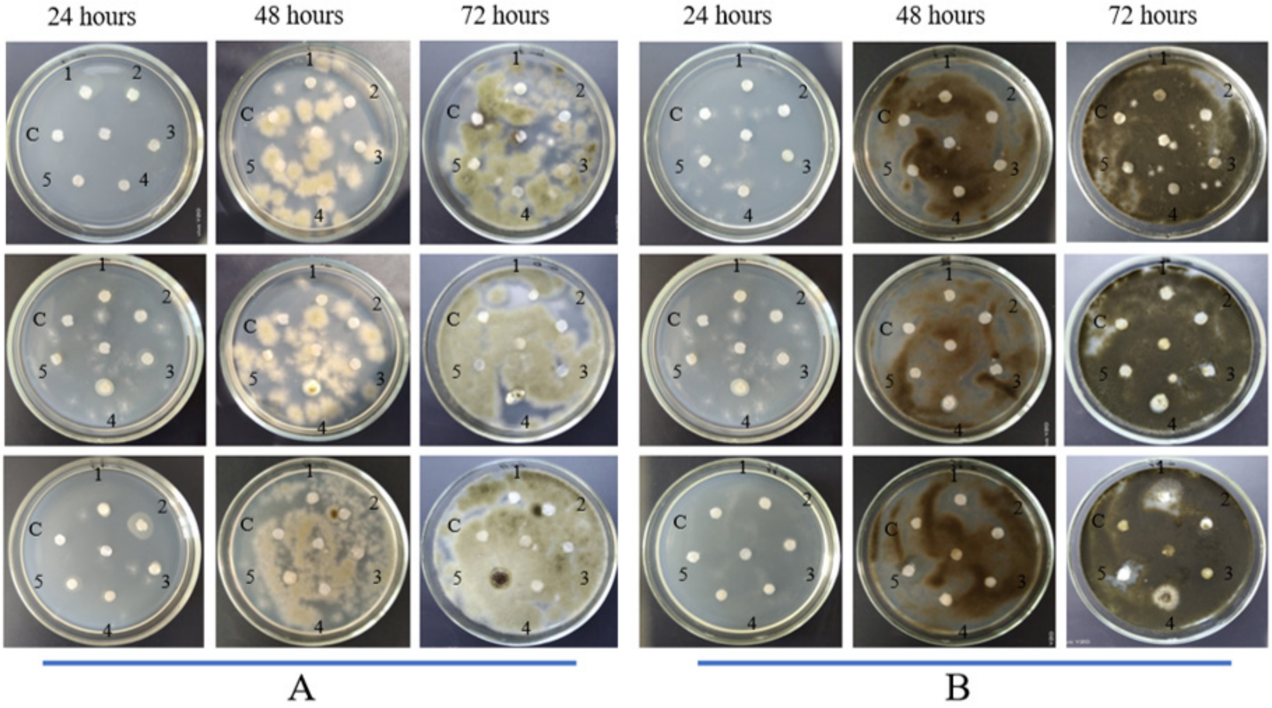

Figure 5 – Activity of nanopreparations against the phytopathogen *A. tenuis* using the disk diffusion method:
A – 1st isolate, B – 2nd isolate

and observed over three days. Within 24 hours, it was visually confirmed that one *A. tenuis* isolate exhibited high sensitivity to all nanopreparations, resulting in complete or partial inhibition zones against the phytopathogenic fungus. Throughout the first day, no visible growth or conidia formation occurred around the mega-disks, and the nutrient substrate color remained unchanged. These observations indicate the presence of fungicidal activity in nanopreparations against *Alternaria* spp.

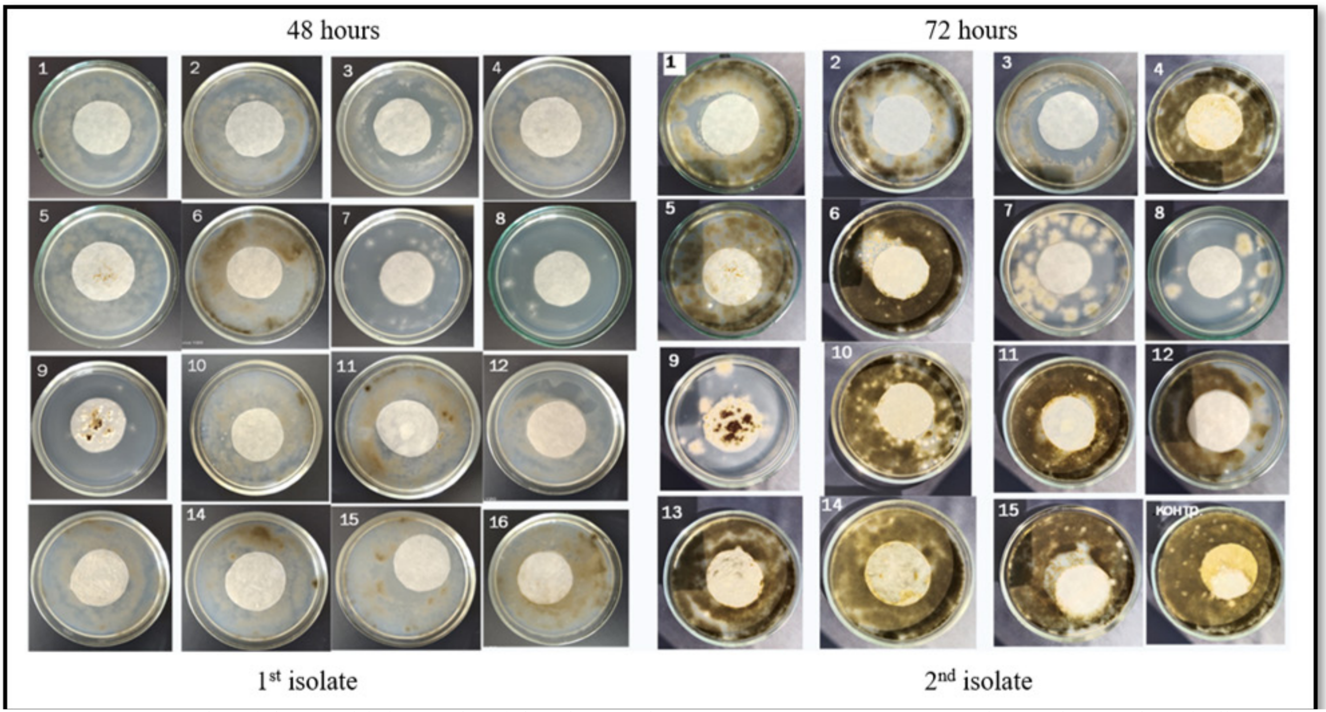

Figure 6 – Results of the sensitivity study of the phytopathogen *A. tenuis* to nanopreparations. The numbers indicate the nanopreparation number.

Observations on the second day revealed visible mycelial growth and the formation of pathogenic conidia on the nutrient agar. By the 48-hour mark, several nanopreparations exhibited either a clear fungicidal or stimulating effect on the phytopathogenic fungus *A. tenuis*: preparation No. 3 demonstrated high fungicidal activity, while preparations No. 1 and No. 7 showed moderate fungicidal activity. Nanopreparations No. 6, No. 10, No. 11, No. 13, and No. 14 displayed a stimulating effect, characterized by increased phytopathogen growth around the disks. Observations on the subsequent third day showed further enhancement of both fungicidal and stimulating effects after 72 hours (Figure 6).

As depicted in Figure 6, the second isolate of *A. tenuis* exhibited significant fungistatic activity towards nanopreparations No. 1, No. 2, No. 3, and No. 8 after 72 hours. This was evident from the presence of zones where colony growth

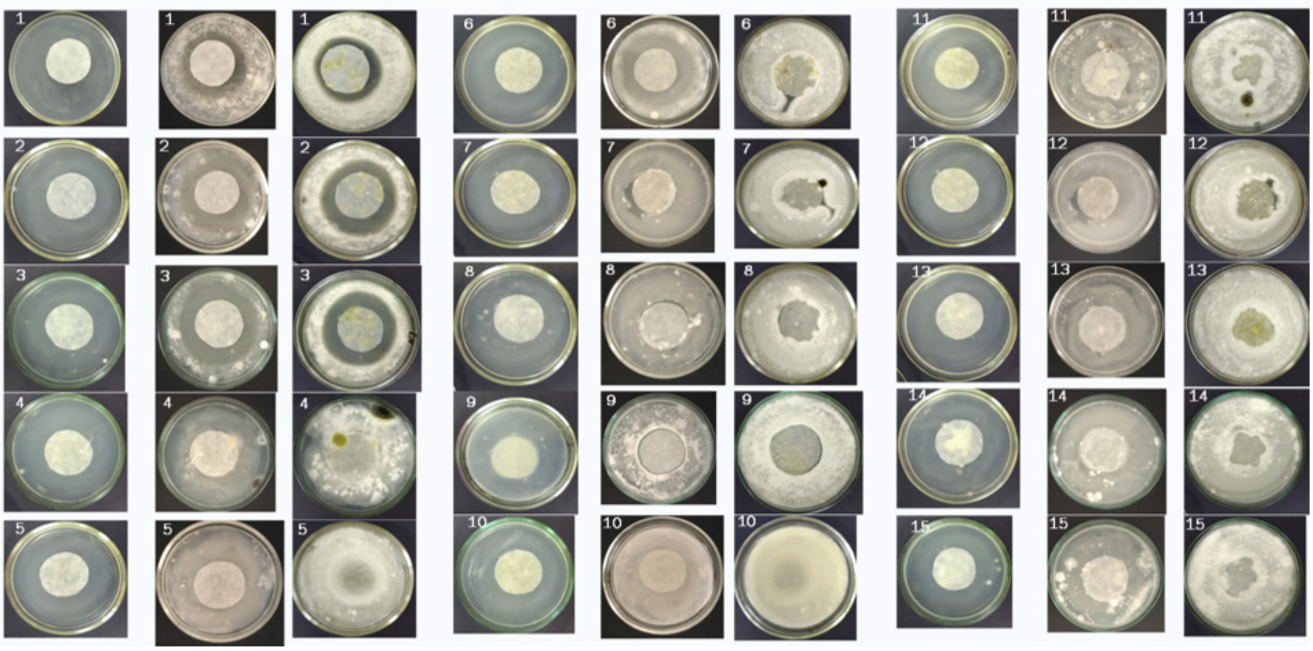

Figure 7 – Results of the study of the sensitivity of the phytopathogen *F. solani* to nanopreparations. The numbers indicate the number of the nanopreparation.

was partially inhibited around the disks. Nanopreparations No. 5 and No. 13 showed a moderate fungistatic effect, characterized by slowed growth and absence of spore formation in the isolate. Conversely, nanopreparations No. 14 and No. 11 demonstrated a stimulating effect, resulting in more vigorous phytopathogen growth around the disks. In summary, the sensitivity analysis of two isolates of *A. tenuis* to nanopreparations indicated that after 72 hours, preparation No. 3 (Novochizol 1%, Na2SO4 1.2%, Cu2+ 1.95 mg/ml as sulfate) exhibited the most pronounced fungicidal effect.

The sensitivity assessment of the phytopathogen *F. solani* to Novochizol preparations using the mega-disc method revealed the formation of growth inhibition zones around the following disks: Preparation No. 1: Novochizol 1%, Cu2+ 1.95 mg/ml; Preparation No. 2: Novochizol 1%, CuSO4, Cu2+ 1.95 mg/ml; Preparation No. 3: Novochizol 1%, Na2SO4 1.2%, Cu2+ 1.95 mg/ml (as sulfate).

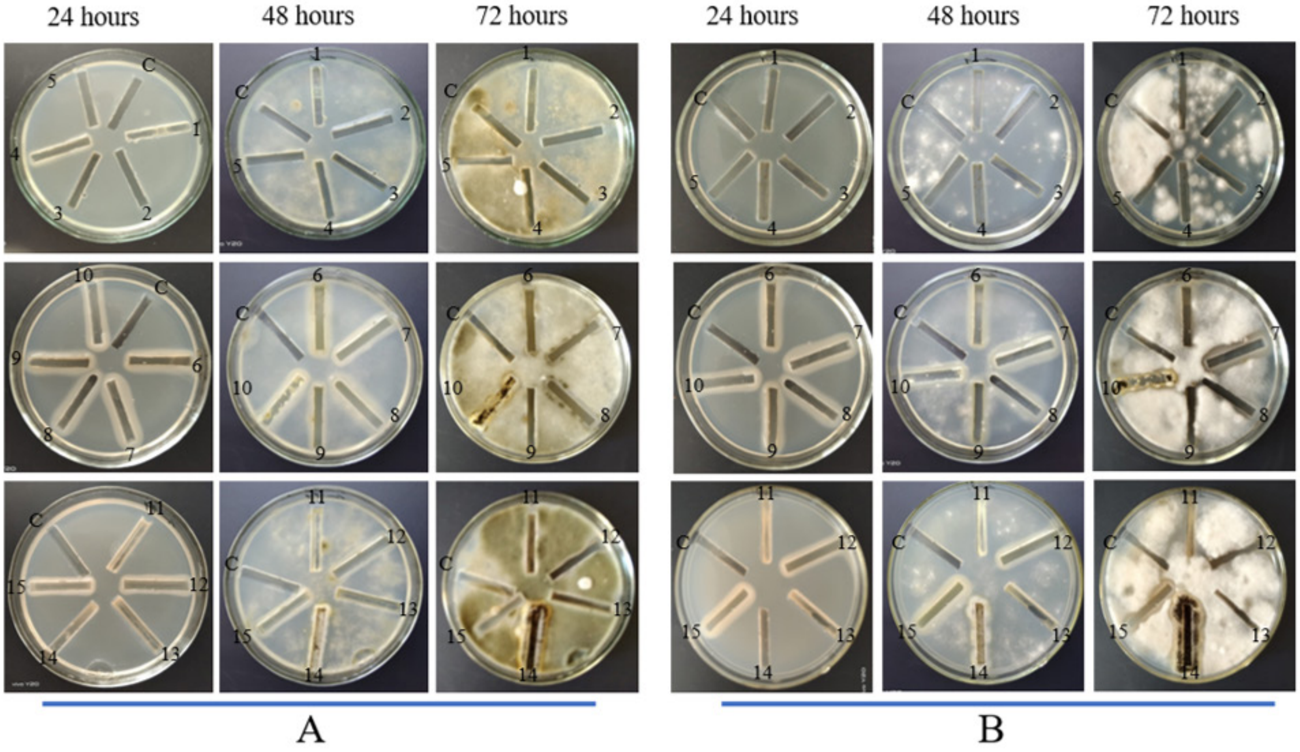

Figure 8 – Results of the sensitivity analysis of the phytopathogenic fungus *Alternaria tenuis* against Novochizol preparations: A - 1st isolate, B - 2nd isolate

Additionally, as nanopreparations accumulated in the agar, the isolate's sensitivity to them increased, resulting in expanded growth inhibition zones of the fungus by 72 hours. Furthermore, *F. solani* demonstrated continued sensitivity to nanopreparation No. 6, which exerted a fungistatic effect by partially suppressing phytopathogen growth within 48 hours. However, sensitivity to the other nanopreparations was observed only during the initial 24 hours, after which they stimulated phytopathogen growth (Figure 7).

Subsequently, to validate the obtained data, a sensitivity determination method using the groove technique was employed to assess two isolates of the phytopathogen *A. tenuis* against Novokhizol nanopreparations. During the initial 24 hours, no phytopathogen growth was observed on the Petri dish surfaces. By the 48-hour mark, it was evident that: the most sensitive isolate of the phytopathogenic fungus *A. tenuis* exhibited no growth in response to preparations No. 1, No. 2, and No. 3. The second isolate of *A. tenuis* displayed heightened sensitivity after 48 hours to nanopreparations No. 2, No. 3, No. 4, and No. 7, indicated by pronounced zones devoid of growth around the grooves. Isolate 2 also demonstrated moderate sensitivity to nanopreparations No. 9 and No. 10 (Figure 8). These findings underscore the varying degrees of sensitivity of *A. tenuis* isolates to specific Novokhizol nanopreparations, confirming the effectiveness of the groove method in assessing fungal response.

As depicted in Figure 8, both isolates of *A. tenuis* exhibited high sensitivity to preparations No. 1, No. 2, and No. 3, which possess fungistatic activity. This sensitivity was evident from the presence of zones where fungal growth was completely inhibited.

4. DISCUSSION

Previous studies have indicated that Novochizol possesses a positive charge, which enhances its ability to interact effectively with various types of molecules. This positive charge is believed to contribute to the antimicrobial activity, similar to chitosan, by interacting with the negatively charged cell membranes of microorganisms. Unlike chitosan, which is a linear polymer, Novochizol has a globular, almost spherical shape due to intramolecular crosslinking. These unique properties of Novochizol make it well-suited for use in systems involving hydrophilic antibiotics with slow release (Table 2).

Novochizol offers several advantages over chitosan, primarily as a carrier for active ingredients. Its nanospherical structure facilitates a significantly higher diffusion rate compared to conventional linear chitosan, which is particularly beneficial for impregnating materials. Novochizol™ technology enables targeted delivery of a wide range of active pharmaceutical ingredients (APIs) such as small molecules, peptides, nucleic acids, and proteins to various cells. This delivery can be achieved through injection, spraying, or topical application, ensuring efficient drug delivery to targeted tissues [29].

Published literature supports the effective antifungal properties of chitosan and its derivatives against diverse phytopathogens [6, 24, 26]. Analysis conducted on berry crop contamination in Astana revealed that 100% of red currants, black currants, raspberries, and strawberries were infected with mycosis pathogens [6]. This underscores the necessity for implementing measures to protect and manage diseases to ensure a high-quality berry harvest.

Our research in berry crops in the northern Kazakhstan zone identified widespread phytopathogenic fungi, particularly *Alternaria* spp. and *Fusarium* spp. The study encompassed the analysis of 15 antifungal nanopreparations containing copper, sulfur, and complex compounds. Despite the variety of preparations tested, only a few showed significant effectiveness in controlling the growth of *Alternaria* spp. Among them, copper-based preparation No. 3 Novochizol demonstrated the highest efficacy. It exhibited a minimum inhibitory concentration (MIC) of 15 µg/ml, with a colony growth inhibition zone exceeding 11 mm around the disk, one of the largest values observed among the preparations tested. However, some preparations did not display notable fungicidal activity, indicating a need for further investigation into their antifungal properties.

Table 2 – Comparative characteristics of chitosan and Novochizol™ [50].

Characteristic	Hitosan	Novohizol ™
Solubility	solubility only at acidic pH	solubility/dispersibility under all conditions
Viscosity	high viscosity	low viscosity
Biodegradability	rapid biodegradation	slow biodegradation
Chemical stability	low physical and chemical stability	high physical and chemical stability
Frost resistance	none	yes
Physical states	limited physical properties	aqueous suspensions, aerosols, hydrogels, solids
Molecular constancy	batch-to-batch heterogeneity	batch-to-batch standardization
Substance transport capacity	limited carrier capabilities	sustained release of virtually any API

Analysis of mycosis pathogen contamination in berry crops in Astana revealed that garden strawberries, common raspberries, black currants, and red currants were all 100% contaminated with various phytopathogens. Our findings align with those of Simões et al. (2023), who also reported high contamination levels in cultivated plants [31]. Specifically, *A. tenuis* and *F. solani* were isolated from the leaves of red currants, garden strawberries, and common raspberries, while black currant leaves harbored multiple types of micromycetes. Notably, *A. tenuis* isolates exhibited diverse morphological characteristics such as color, colony shape, presence of conidia, and varied sensitivity to the antifungal properties of Novochizol nanopreparations.

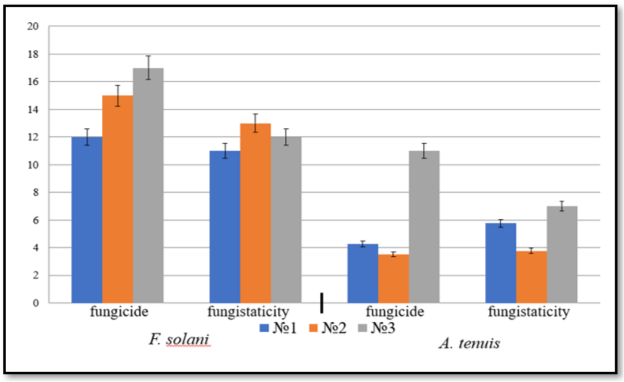

Figure 9 – Comparative analysis of the sensitivity of phytopathogens F. solani and *A. tenuis* to nanopreparations No. 1, No. 2 and No. 3.

The sensitivity testing of berry crop pathogens to Novochizol nanopreparations highlighted preparations No. 1, No. 2, and No. 3 as the most effective against phytopathogenic fungi. Their fungicidal effect was evident from the complete absence of fungal growth on nutrient media around the disks during laboratory studies and the absence of lesions on berry crop leaves in field conditions. Statistical analysis of sensitivity data for *A. tenuis* and *F. solani* over a three-day period consistently showed preparation No. 3 to possess superior antifungal properties (Figure 9).

As depicted in Figure 9, the pathogen *F. solani* shows sensitivity to three Novochizol nanopreparations: Preparation No. 1: Novochizol 1% Cu2+ 0.95 mg/ml; Preparation No. 2: Novochizol 1.8% Cu2+ 0.22 mg/ml Matryoshka; Preparation No. 3: Novochizol 1% Cu2+ 0.98 mg/ml. Among these, preparation No. 3 demonstrates higher fungicidal activity against *F. solani*, preparation No. 2 exhibits average activity, and preparation No. 1 shows weaker activity. In terms of fungistatic properties against *F. solani*, preparation No. 2 displays more pronounced effects, followed by preparation No. 3, and preparation No. 1 shows the least activity.

The sensitivity of the phytopathogen *A. tenuis* to these three Novochizol nanopreparations correlates positively in terms of both fungicidal and fungistatic properties, with a correlation coefficient of 0.845. Preparation No. 3 exhibits higher antifungal activity against *A. tenuis*, preparation No. 1 shows average activity, and preparation No. 2 demonstrates lower antifungal activity.

For *F. solani*, the sensitivity to the same Novochizol nanopreparations shows a weak positive correlation with a coefficient of 0.596. However, a stronger positive correlation of 0.746 is observed in terms of fungicidal activity of all three nanopreparations against both pathogens, while a negative correlation of -0.609 is noted in terms of their fungistatic activity.

CONCLUSION

Based on the findings from our study on berry crop mycoses in Astana city summer cottages, the following conclusions can be drawn:

1. The predominant pathogens affecting berry crops are *A. tenuis* and *F. solani*, with a 100% infection rate observed in red and black currants, common raspberries, and garden strawberries.

2. There is a direct positive correlation of 0.993 between the growth of phytopathogens on different types of berry crops. Black currants exhibited more active micromycete growth compared to common raspberries.

3. Analysis of the sensitivity of *A. tenuis* and *F. solani* to Novochizol nanopreparations revealed the following: *A. tenuis* is highly sensitive to preparations No. 1, No. 2, No. 3, No. 11, and No. 9 in terms of their antifungal effects; *F. solani* shows sensitivity to preparations No. 1, No. 2, and No. 3.

4. The sensitivity of *A. tenuis* to Novochizol nanopreparations correlates positively with both fungicidal and fungistatic properties, with a correlation coefficient of 0.845. In contrast, the sensitivity of *F. solani* to the same nanopreparations exhibits a weaker positive correlation, with a coefficient of 0.596, indicating less consistent sensitivity across the tested preparations.

These conclusions highlight the effectiveness of specific Novochizol nanopreparations against *A. tenuis* and *F. solani* in controlling berry crop mycoses, underscoring the need for targeted antifungal strategies in agricultural practices.

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CONFLICT OF INTEREST

There are no conflicts of interest to declare.

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ЧУВСТВИТЕЛЬНОСТЬ ФИТОПАТОГЕНОВ ЯГОДНЫХ КУЛЬТУР К НАНОПРЕПАРАТАМ НОВОХИЗОЛЯ IN VITRO

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АБСТРАКТ

Грибковые заболевания широко распространены среди сельскохозяйственных растений, составляя более 80% всех болезней. Например, ягодные культуры подвержены ряду грибковых инфекций, таких как головня, ржавчина и корневая гниль. В некоторых регионах эти заболевания могут вызывать потери урожая, превышающие 70%. Показано in vitro фунгицидное действие нанопрепаратов «Новохизол», содержащих серу и медь, на патогенные грибы родов *Alternaria* и *Fusarium*. Анализ чувствительности *Alternaria tenuis* и *Fusarium solani* к данным нанопрепаратам выявил, что наибольшую чувствительность возбудители альтернариоза проявили к препаратам № 1, № 2, № 3, № 11 и № 9. Аналогично, *Fusarium solani* был наиболее чувствителен к препаратам № 1, № 2 и № 3. Чувствительность *Alternaria tenuis* к нанопрепаратам «Новохизол» положительно коррелирует с их фунгицидными и фунгистатическими свойствами с коэффициентом корреляции 0,845. Напротив, чувствительность *Fusarium solani* к этим же нанопрепаратам показала более слабую положительную корреляцию с коэффициентом 0,596.

Ключевые слова: нанопрепарат, Новохизоль, фитопатогенные грибы, фунгицидная активность, чувствительность, ягодные культуры.

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ЖИДЕК ДАҚЫЛДАРЫНЫҢ ФИТОПАТОГЕНДЕРІНІҢ IN VITRO НОВОХИЗОЛ НАНОПРЕПАРАТТАРЫНА СЕЗІМТАЛДЫҒЫ

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АҢДАТПА

Саңырауқұлақ аурулары ауылшаруашылық өсімдіктерінің арасында кең таралған, барлық аурулардың 80% -дан астамын құрайды. Мысалы, жидек дақылдары қоқыс, тот және тамыр шірігі сияқты бірқатар саңырауқұлақ инфекцияларына сезімтал. Кейбір аймақтарда бұл аурулар 70%-дан астам егіннің жоғалуына әкелуі мүмкін. Құрамында күкірт пен мыс бар Novohizol нанопрепараттарының *Alternaria* және *Fusarium* тектес патогенді саңырауқұлақтарға in vitro фунгицидтік әсері көрсетілді. Осы нанопрепараттарға *Alternaria tenuis* және *Fusarium solani* сезімталдығын талдау Альтернария қоздырғыштары №1, №2, №3, №11 және №9 препараттарға ең жоғары сезімталдықты көрсеткені анықталды. Сол сияқты *Fusarium solani* №1, №2 және №3 препараттарға ең сезімтал болды. *Alternaria tenuis* «Новохизол» нанопрепараттарына сезімталдығы олардың фунгицидтік және фунгистатикалық қасиеттерімен 0,845 корреляция коэффициентімен оң корреляцияланады. Керісінше, *Fusarium solani*-нің бірдей наномедәрілерге сезімталдығы 0,596 коэффициентімен әлсіз оң корреляцияны көрсетті.

Түйін сөздер: нанопрепарат, Новохизоль, фитопатогенді саңырауқұлақтар, фунгицидтік белсенділік, сезімталдық, жидек дақылдары.