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PHYTOSANITARY ASSESSMENT OF WHEAT AND BARLEY SEEDS TREATED WITH DITHIOCARBAMATES

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Abstract. *Introduction*. Achieving high crop yields in agriculture depends largely on the quality of seeds and planting materials. Seed-borne infections reduce germination capacity and overall plant productivity, highlighting the need for treatments that combine growth-stimulating and fungicidal properties. *This study aimed* to evaluate the stimulant and antifungal effects of aqueous solutions of dithiocarbamates on wheat and barley seeds, identify optimal concentrations, and assess their impact on seed quality and pathogenic microflora. *Results and Discussion.* Seeds of wheat and barley were treated with five dithiocarbamate-containing preparations at concentrations of 0.001%, 0.01%, and 0.1%. Germination energy, laboratory germination, seedling growth intensity, microbial activity, and percentage of infected seeds were assessed. At a concentration of 0.001%, wheat seeds treated with Preparations 1 and 3-5 showed high germination rates (94.0-96.6%), although infection levels varied (6.0-27.3%). In barley, Preparations 2-5 demonstrated significant stimulation of germination (93.0-98.0%) and reduced seed infection to 8.0-22.0%. The most pronounced antifungal activity in barley was observed for Preparations 1 and 3, reducing infection to 10.0-12.0% and 9.0-11.3%, respectively, compared to 77.3% in the control. In wheat, Preparations 3 and 5 effectively reduced infection rates to 10.6-19.0% and 6.0-16.0%, respectively. *Conclusion.* The results suggest that dithiocarbamate-containing preparations can enhance seed viability while limiting pathogen development. Two compounds were most effective: Preparation 5 (sodium benzylmethylcarbamodithioate) for wheat and Preparation 3 (sodium dibenzylcarbamodithioate) for barley. These findings support their potential use as dual-action seed treatments in cereal crop production.

Key words: phyto expertise, dithiocarbamate, germination energy, laboratory germination, seed infection, test crops (wheat, barley).

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1. Introduction

In the Development Concept of the Agro-Industrial Complex of the Republic of Kazakhstan for 2021-2030, sustainable development of crop production with high and stable yields adapted to climate change is identified as a key priority [1]. Achieving the full potential of productivity and yield stability largely depends on the use of effective agronomic practices, as well as the application of safe plant protection products suited to the agricultural conditions of Kazakhstan.

Although global grain production has shown an upward trend in recent years, wheat yield losses due to diseases still account for approximately 10% of potential harvests worldwide. Experts emphasize that the implementation of modern agricultural practices, crop rotation with resistant varieties, and timely treatment of crops with crop protection chemicals (CPCs) can significantly reduce disease-related losses [2-4].

An analysis of seed samples collected in Kazakhstan in 2021 revealed the presence of a pathogenic complex across all cultivated crops, despite the previous year's drought. This complex included polyphagous fungi such as Fusarium (5-15%), Alternaria (5-40%), molds (1-10%), and specialized pathogenic species (3-15%). Infected seeds exhibited low germination rates and reduced germination energy, resulting in lower grain mass and poor ear filling – factors that substantially affect crop quality.

Effective plant disease prevention and protection are based on accurate diagnostics, including an understanding of disease etiology and development. Seed treatment with fungicides (seed dressings) must be preceded by phytopathological examination, which determines the seed's suitability for sowing and the need for chemical treatment. Therefore, seed dressing remains an essential step for effectively controlling the spread and development of pathogenic microorganisms that can damage seedlings.

The aim of this study is to investigate the growth-stimulating effects of aqueous solutions of dithiocarbamate-containing preparations, determine the optimal concentrations for enhancing germination energy and laboratory germination rates, and assess their fungicidal properties using test crops.

2. Experimental part

The phytosanitary assessment of seeds was conducted at the Laboratory of Phytopathology, Zh. Zhiembayev Kazakh Research Institute for Plant Protection and Quarantine. The test materials consisted of seeds from two model crops: wheat and barley.

Seed treatment was performed by moistening the seeds in chambers with aqueous solutions of the test compounds at concentrations of 0.001%, 0.01%, and 0.1%. For the control group, seeds were moistened with distilled water. As a reference treatment, the fungicide TMTD (tetramethylthiuram disulfide) was used at a concentration of 0.04%. Each treatment was tested using three replicates of 50 seeds. Seed surface inspection was carried out to identify pathological changes, following standard visual assessment techniques for wheat and barley grains [5]. Fungicide efficacy was evaluated based on the number of infected seeds. Germination energy (assessed on day 3) and laboratory germination (assessed on day 7) were measured according to standardized procedures [6].

The test dithiocarbamate-containing compounds used for biological evaluation included:

Preparation 1: Sodium (2-morpholinoethyl)carbamodithioate [7,8];

Preparation 2: Sodium 1H-1,2,4-triazole-1-carbodithioate [9];

Preparation 3: Sodium dibenzylcarbamodithioate [10];

Preparation 4: Sodium diphenylcarbamodithioate [11];

Preparation 5: Sodium benzyl(methyl)carbamodithioate [12].

Experimental scheme: 1. Control (untreated); 2. Standard: TMTD fungicide (0.04%); 3. Dithiocarbamate-containing preparations 1-5 at concentrations of 0.001%, 0.01%, and 0.1%.

3. Results and discussion

Dithiocarbamates have demonstrated high efficacy in the control of fungal plant diseases and are considered a promising group of compounds due to their strong fungicidal properties. These fungicides are widely used in agriculture to combat a range of plant pathogens, including root rot, scab, common bunt, seed mold, Fusarium spp., powdery mildew, and others. As a result, dithiocarbamates are extensively applied in the protection of various crops.

Among the most commonly used dithiocarbamate fungicides are Mancozeb, Maneb, Zineb, Ziram, Metiram, Propineb, and Ferbam. These fungicides are used for protecting cereals, legumes, vegetables, fruits, and ornamental plants against numerous fungal infections. Their effectiveness and broad spectrum of activity make dithiocarbamates a valuable tool in integrated plant protection systems, contributing to enhanced crop yield and improved agricultural product quality [13-16].

For the current study, five dithiocarbamate-containing compounds were selected for biological evaluation: two heterocyclic dithiocarbamates (Preparation 1 and Preparation 2) and three aromatic dithiocarbamates (Preparations 3-5). Investigated dithiocarbamate-containing preparations are presented in Figure 1.

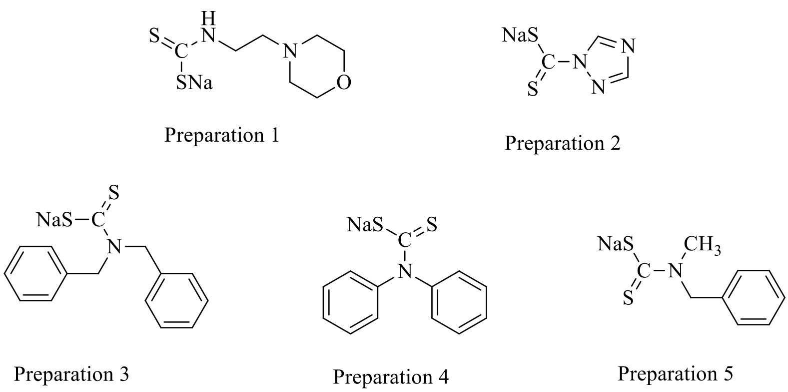


Figure 1 – Dithiocarbamate-containing preparations

These dithiocarbamate-containing compounds were tested according to the experimental scheme above described. The goal was to assess their fungicidal activity, as well as their growth-stimulating effects on seed germination and early seedling development in wheat and barley under laboratory conditions.

The results of the phytosanitary assessment of wheat and barley seeds indicate a positive effect of treatment with various dithiocarbamate-containing preparations 1-5 on seed quality, particularly in terms of germination energy and laboratory germination, compared to the control. However, the effectiveness of the preparations varied depending on the crop species, concentration of the active substance, and the parameter assessed.

Phytosanitary assessment of wheat seeds.

In the control variant, high germination energy and laboratory germination were observed (both at 95.3%), but these were accompanied by intense microbial growth and 100% seed infection, indicating high pathogen load. The main part of the pathogenic microflora on the seeds consisted of fungi of the genera Mucor sp., Penicillium sp. and Alternaria sp. The standard fungicide TMTD ensured effective seed protection, reducing infection to 0.6% and suppressing microbial growth while maintaining germination at 96.0%. The results of the phytosanitary assessment of wheat seeds are shown in Figure 2.

Among the tested preparations, preparation 5 was the most effective based on a combination of biological indicators. At concentrations of 0.001% and 0.01%, it ensured high germination (up to 97.6%), strong seedling growth, and a significant reduction in microbial activity and seed infection (as low as 6%).

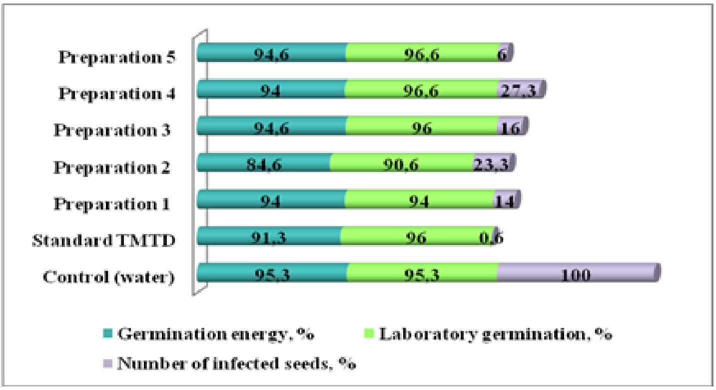
Preparation 3 also showed good results, particularly at 0.001% and 0.01% concentrations, with germination reaching 96%, reduced microbial growth, and infection rates lowered to 10.6-16%. However, at 0.1% concentration, germination dropped sharply to 82%, and microbial activity increased.

Preparations 1, 2, and 4 exhibited less consistent performance. For instance, preparation 2 showed low fungicidal activity, and the percentage of infected seeds remained elevated (up to 26%) across all concentrations. Preparation 1 showed stable germination but did not effectively reduce microbial load. Preparation 4 led to high seedling vigor, but infection levels remained high, especially at 0.001% concentration (up to 27.3%).

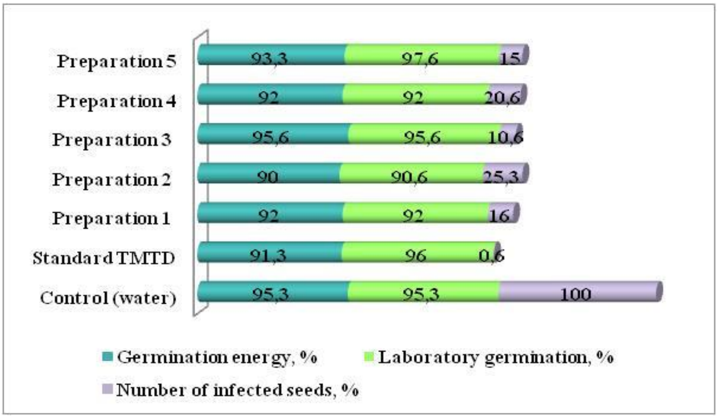
Thus, preparations 3 and 5, especially at lower concentrations, demonstrated promising fungicidal activity without compromising seed viability and can be considered for practical application in wheat cultivation.

Phytosanitary assessment of barley seeds.

A similar trend to that observed in wheat was identified in barley. In the control variant, seed infection reached 77.3%, accompanied by intense microbial growth, highlighting the presence of seed-borne pathogens. The reference fungicide TMTD (4 L/t) effectively reduced infection levels to 2.6%, with minimal microbial growth, and maintained high laboratory germination (94.6%). The results of the phytosanitary assessment of barley seeds are shown in Figure 3.



(a)



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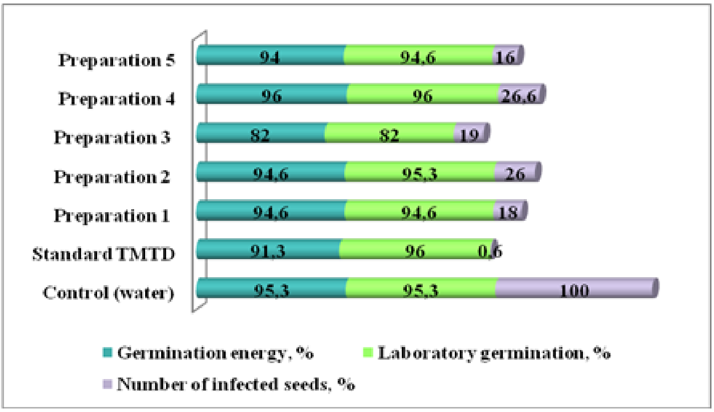
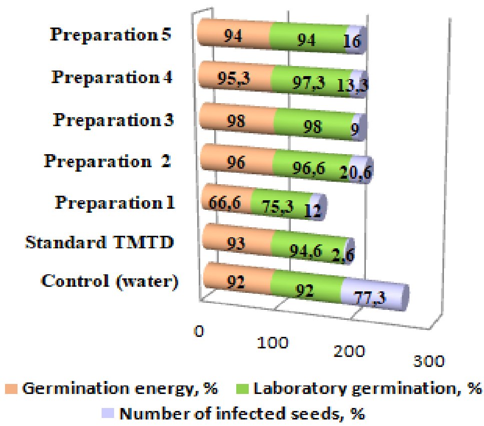


(c)

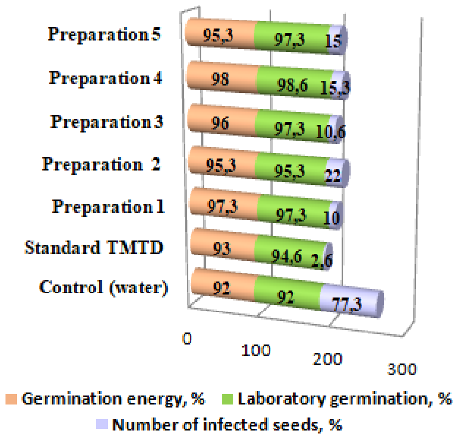
Figure 2 – Phytosanitary assessment of wheat seeds after treatment with preparations 1-5 at 0.001% (a), 0.01% (b), and 0.1% (c) concentrations.

Preparation 3 consistently showed the highest efficacy at all tested concentrations. At 0.001% and 0.01%, laboratory germination reached 98.0% and 97.3%, respectively, while antifungal activity remained high, and the proportion of infected seeds did not exceed 10.6%. These results demonstrate both strong protective and stimulant properties.

Preparation 4 also showed excellent results, particularly at 0.01% and 0.1%. Germination reached 98.6% at 0.01%, and seed infection was limited to 8-15.3%. Microbial development remained low, and seedling growth intensity was consistently high, indicating both antifungal and growth-stimulating effects.



(a)



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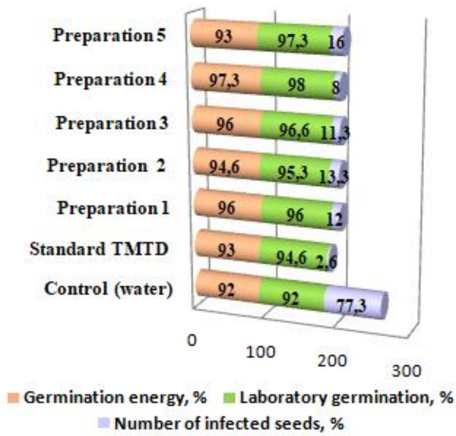

(c)

Figure 3 – Phytosanitary assessment of barley seeds after treatment with preparations 1-5 at 0.001% (a), 0.01% (b), and 0.1% (c) concentrations.

Preparation 5 also demonstrated notable effectiveness. At 0.001% concentration, it provided moderate control of seed infection (16.0%) with acceptable germination (94.0%) and high antifungal activity. At 0.01%, it achieved improved performance – germination rose to 97.3%, with infection decreasing to 15.0% and microbial growth remaining low. The best results for preparation 5 were observed at 0.1%, where laboratory germination remained at 97.3%, antifungal activity decreased slightly, but seedling vigor was high, and infection levels were held at 16.0%. These data suggest that preparation 5 offers stable protection and growth stimulation, particularly at medium and high concentrations, although its fungicidal activity was somewhat lower compared to preparation 3.

In contrast, preparation 1 at 0.001% caused a significant decline in germination energy (66.6%) and final germination (75.3%), suggesting phytotoxicity or incompatibility at this concentration. However, increased concentrations led to recovery of seed viability.

Preparation 2 showed limited efficacy in barley: antifungal activity remained low, and seed infection levels ranged between 13.3% and 22.0%, regardless of concentration.

A comparison of the tested preparations at equivalent concentrations revealed that at 0.001%, preparations 3 and 5 showed the best results in both crops, providing effective microbial control and stimulating seedling growth. At 0.01%, preparations 3 and 4 maintained high germination rates and low infection. At 0.1%, a number of preparations (notably preparations 3 and 1) showed reduced performance, possibly due to phytotoxicity or overstimulation of microbial growth.

The results indicate that preparations 3 and 5 are the most effective among the tested compounds. They combine fungicidal activity with positive effects on seedling development and germination. These preparations are particularly promising for use as environmentally safer alternatives to conventional chemical fungicides in wheat and barley seed treatment.

4. Conclusion

The results of this study demonstrate that aqueous solutions of dithiocarbamates, applied at concentrations of 0.001-0.1%, exhibit both growth-stimulating and antifungal properties when used for seed treatment of wheat and barley. Seeds treated with dithiocarbamate-containing preparations showed improved germination energy and laboratory germination compared to the untreated control, with values reaching up to 96.0% in wheat and 98.6% in barley.

In addition to enhancing germination parameters, the tested dithiocarbamates effectively reduced the level of seed-borne fungal infections. Infection rates in treated variants were significantly lower – ranging from 6.0% to 27.3% in wheat and from 8.0% to 22.0% in barley – compared to 100% and 77.3% in the control, respectively. This confirms the protective effect of dithiocarbamates against phytopathogens commonly associated with cereal seeds.

Among the tested compounds, preparation 3 (sodium dibenzylcarbamodithioate) and preparation 5 (sodium benzyl(methyl)carbamodithioate) showed the most promising results in barley and wheat, respectively, providing a favorable balance between biological efficacy and germination stimulation.

The findings suggest that dithiocarbamates may serve as effective seed treatment agents with dual functionality – promoting early seedling development and suppressing pathogenic microflora. These results support their further investigation under field conditions and their potential integration into sustainable crop production systems as an alternative to traditional chemical fungicides.

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Conflict of Interest: All authors declare that they have no conflict of interest.

ДИТИОКАРБАМАТТАРМЕН ӨҢДЕЛГЕН БИДАЙ ЖӘНЕ АРПА ТҰҚЫМДАРЫНЫҢ ФИТОЭКСПЕРТИЗАСЫ

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Түйіндеме. *Кіріспе.* Ауыл шаруашылығында жоғары өнімділікке қол жеткізу көбінесе тұқымдар мен отырғызу материалының сапасына байланысты. Дәнді дақылдардың тұқымдық инфекциясы өну энергиясын және өсімдіктердің жалпы өнімділігін төмендетеді, бұл өсуді ынталандыратын және фунгицидтік қасиеттерді біріктіріп өңдеу қажеттілігін көрсетеді. *Бұл зерттеудің мақсаты* дитиокарбаматтардың сулы ерітінділерінің бидай мен арпа тұқымдарына биостимуляциялық және фунгицидтік әсерін бағалау, оңтайлы концентрацияны анықтау және олардың тұқым сапасы мен патогендік микрофлораға әсерін зерттеу. *Нәтижелер және талқылау.* Бидай мен арпа тұқымдары 0.001%, 0.01% және 0.1% концентрациясында бес дитиокарбаматқұрамдас препараттармен өңделді. Өну энергиясы, зертханалық өнгіштік, көшеттердің өсу қарқындылығы, микробтық белсенділік және зақымдалған тұқымдардың пайызы бағаланды. 0.001% концентрациясында 1 және 3-5 препараттарымен өңделген бидай тұқымдары жоғары өну көрсеткіштерін көрсетті (94.0-96.6%), бірақ инфекция деңгейі әр түрлі болды (6.0-27.3%). Арпада 2-5 препараттар өнгіштіктің едәуір артуына (93.0-98.0%) және инфекцияның 8.0-22.0% дейін төмендеуіне ықпал етті. Арпадағы ең үлкен фунгицидтік белсенділік 1 және 3 препараттарда байқалды – инфекция сәйкесінше 10.0-12.0% және 9.0-11.3% дейін төмендеді (бақылаумен салыстырғанда-77.3%). Бидайда 3 және 5 препараттар тиімді болды – инфекция деңгейі сәйкесінше 10.6-19.0% және 6.0-16.0% құрады. *Қорытынды.* Дитиокарбаматқұрамдас препараттар тұқымның өміршеңдігін арттыруға және сонымен қатар патогендердің дамуын шектеуге қабілетті екендігіні нәтижелер көрсетті. Оның ішінде бидайға арналған 5-препарат (натрий бензилметилкарбамодитиоаты) және арпаға арналған 3-препарат (натрий дибензилкарбамодитиоаты) ең тиімді болып шықты. Бұл қосылыстардың дәнді дақылдардың тұқымын егу алдында өңдеуде қосарланған әсер ету құралы ретінде қолдану мүмкіндігі бар.

Түйін сөздер: фитоэкспертиза, дитиокарбаматтар, өну энергиясы, зертханалық өнгіштік, тұқымның зақымдануы, сынақ дақылдары (бидай, арпа).

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ФИТОЭКСПЕРТИЗА СЕМЯН ПШЕНИЦЫ И ЯЧМЕНЯ, ОБРАБОТАННЫХ ДИТИОКАРБАМАТАМИ

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Резюме. *Введение.* Достижение высоких урожаев в сельском хозяйстве во многом зависит от качества семян и посадочного материала. Семенная инфекция зерновых культур снижает энергию прорастания и общую продуктивность растений, что подчеркивает необходимость обработки, сочетающей ростстимулирующие и фунгицидные свойства. *Целью данного исследования* было оценить биостимулирующее и фунгицидное действие водных растворов дитиокарбаматов на семена пшеницы и ячменя, определить оптимальные концентрации и изучить их влияние на качество семян и патогенную микрофлору. *Результаты и обсуждение.* Семена пшеницы и ячменя обрабатывали пятью дитиокарбамат содержащими препаратами в концентрациях 0.001%, 0.01% и 0.1%. Оценивались энергия прорастания, лабораторная всхожесть, интенсивность роста проростков, микробная активность и процент заражённых семян. При концентрации 0.001% семена пшеницы, обработанные препаратами 1 и 3-5, показали высокие показатели всхожести (94.0-96.6%), однако уровень заражения варьировал (6.0-27.3%). На ячмене препараты 2-5 способствовали значительному увеличению всхожести (93.0-98.0%) и снижению заражения до 8.0-22.0%. Наибольшая фунгицидная активность на ячмене отмечена у препаратов 1 и 3 – заражение снизилось до 10.0-12.0% и 9.0-11.3%, соответственно (по сравнению с контролем – 77.3%). На пшенице эффективными оказались препараты 3 и 5 – уровень заражения составил 10.6-19.0% и 6.0-16.0%, соответственно. *Заключение.* Результаты показывают, что дитиокарбамат содержащие препараты способны повышать жизнеспособность семян и одновременно ограничивать развитие патогенов. Наиболее эффективными оказались: препарат 5 (бензилметилкарбамодитиоат натрия) для пшеницы и препарат 3 (дибензилкарбамодитиоат натрия) для ячменя. Эти соединения имеют потенциал применения в качестве средств двойного действия при предпосевной обработке семян зерновых культур.

Ключевые слова: фитоэкспертиза, дитиокарбамат, энергия прорастания, лабораторная всхожесть, зараженность семян, тест-культуры (пшеница, ячмень).

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