RESEARCH ARTICLE

SABRAO Journal of Breeding and Genetics
57 (6) 2457-2466, 2025
http://doi.org/10.54910/sabrao2025.57.6.19
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

EFFECTIVENESS OF WHEAT AND BARLEY SEEDS' TREATMENT WITH PROTECTIVE AND STIMULATING COMPOSITIONS IN COMBATING SOIL-BORNE DISEASES AND PESTS

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SUMMARY

The study based on the seed treatment with protective and stimulating compositions is novel research with no previous work done in Kazakhstan and other regions worldwide. The phytopathological analysis revealed the fungal and bacterial infections in the samples of wheat and barley seeds cultured with nutrient media. The examined wheat and barley samples displayed contaminations with saprophytic and pathogenic microflora, and fungal infections were predominant. The wheat and barley seed treated with the protective-stimulating compositions Scarlet m.e. (micro emulsion), Tabu w.s.c. (water-suspension concentrate), and potassium humate significantly suppressed the infections caused by fungal and bacterial pathogens. They also enhanced plant resistance to damage caused by soil-dwelling pests and positively influenced seed quality by promoting the growth and development of seedlings and their root systems. By using this formulation, the highest germination energy and seed viability rates resulted in wheat and barley seeds (99.3% and 98.0%, respectively). On the seventh day, seed infection declined by 96.7% (wheat) and 76.7% (barley) compared with the control, which had infection rates of 100% and 91.3%, respectively. Furthermore, the protective-stimulating compositions were cost-effective, reducing pesticide environmental loads due to their low application rates, demonstrating their potential for sustainable agricultural practices.

Communicating Editor: Dr. Sajjad Hussain Qureshi

Manuscript received: April 17, 2025; Accepted: June 29, 2025.

Citation: Kozhabayeva GE, Temreshev II, Kopirova GI, Tusupbayev KB, Kassembayeva NK, Sultanova NZH, Dutbayev YB (2025). Effectiveness of wheat and barley seeds' treatment with protective and stimulating compositions in combating soil-borne diseases and pests. *SABRAO J. Breed. Genet.* 57(6): 2457-2466. http://doi.org/10.54910/sabrao2025.57.6.19.

Keywords: Wheat, barley, seed treatment, protective-stimulating compositions, soil-borne diseases and pests, germination, growth and development

Key findings: The wheat and barley seed treatment with protective-stimulating compositions effectively suppressed the infections caused by fungal and bacterial pathogens and considerably enhanced their viability and germination energy.

INTRODUCTION

Improving seed quality is one of the most economical and effective contributions in agricultural development, as it significantly increases the crop's yield potential (Rocha *et al.,* 2019; Lahlali *et al.,* 2022). Preliminary crop seed testing for disease contamination is important, which also determines the seed germination. Plant diseases and pests lead to crop yield losses of up to 20%–30% and even more. The most harmful diseases transmitted through grain seeds are smut diseases (loose and covered smut in barley and loose smut in oats) and root and basal rots (*Fusarium* and *Helminthosporium* root rots), exhibiting the intensity of mass outbreaks three to six times in 10 years (grain losses up to 30%). Winter crops' damping off happens 2–3 times in a decade (grain losses up to 30%) (Vishunavat *et al.,* 2023). Studies have shown seed treatment with protective and stimulating compounds emerged as the most economical and effective way to protect the seeds and crop plants from diseases and pests (Dell'Olmo *et al.,* 2023; Gurmeet and Simerjeet, 2023; Moumni *et al.,* 2023).

Development of new low-toxic and inexpensive drugs becomes more crucial every year worldwide (Amruta *et al.*, 2023). The seeds' preparation for sowing should begin with their mandatory phytopathological examination, including a microbiological analysis of the composition of fungal and bacterial phytopathogens. The phytopathological examination will provide a concrete basis for decision-making on the advisability of using seeds for sowing and selecting a disinfectant with the required spectrum of action. In this regard, the importance of phyto-expertise of seed material improves in the integrated protection measures (Toropova and Zakharov, 2017).

Seed treatment with systemic fungicides is essential to prevent significant yield and quality losses in wheat. Developing low-dose, complex treatments with biological additives and new modification methods is a promising direction (Vlasenko *et al.,* 2020). Pre-sowing seed treatment of spring wheat (Omskaya 36) and spring barley (Preria) with insecticides (Tabu and Cruiser) and fungicides (Vial Trust and Certikor) used individually or in combination effectively controlled the grain flea and root rot with a biological efficiency of up to 83.4% and 87.9%, respectively. This resulted in yield increases of 0.23–0.51 t/ha in wheat and 0.37–0.47 t/ha in barley (Zargaryan *et al*., 2018).

The plant growth regulator floroxan, developed by the Nesmeyanov Institute of Organoelement Compounds (INEOS RAS), showed the highest efficiency at 100 mg/L and was a promising component in pre-sowing seed treatment. Recent joint research by Russian and Uzbek scientists led to innovative multicomponent protectants for cereals, antidote protectants against metsulfuron-methyl soil residues, and composite preparations used in cotton and vegetables (Khalikov and Chkanikov, 2023). Pea seed treatment with the growth stimulant Biostim Start, alone and in combination with Scarlet fungicide, microemulsion, and Emistim, enhanced the seedling growth (6.9%–16.0%) and green biomass (13.6%–32.9%) and reduced the root rot by 16.2%. These treatments also improved field germination by 6%, boosted yield by up to 0.29 t/ha (9.5%), and increased the pea grain number and weight per plant (Erokhin *et al.,* 2017).

Soybean's pre-sowing seed treatment with fungicides Standak Top and Maxim XL, followed by inoculation with active rhizobia strain 634b, enhances ascorbate peroxidase activity in roots and nodules without promoting lipid peroxidation, supporting effective early legume-rhizobial symbiosis (Mamenko *et al*., 2021). Past studies reported fungicides prothioconazole, tebuconazole, and their combinations with fludioxonil, difenoconazole, and fluoxastrobin considerably reduced the seed-borne *Fusarium* spp., *Bipolaris sorokiniana*, and root rot infection in minimum-tilled barley, spring wheat, and oilseed rape (Sooväli *et al*., 2017).

Alfalfa's pre-sowing seed treatment improved the seed quality, increased seedling growth (6.4%–20.8%), and 75%–85% biological effectiveness against fungal and bacterial infections, including *Penicillium*, *Alternaria*, *Fusarium*, *Pseudomonas,* and *Erwinia*. Biological preparation Extrasol application enhanced the alfalfa growth, raising stalk height by 22.2 cm and plant bushiness by 27.9%, with a 29.1% yield increase (Bekezhanova *et al*., 2020). Effective and eco-friendly seed protection remains a key challenge, and thus, similar protective-stimulating compositions succeeded in developing for grain crops (Dzhaimurzina *et al*., 2020; Kozhabaeva *et al*., 2023).

Seed healing is a practice using peptides, which seem effective and do not have a strong impact on the environment (Yi-Meng *et al*., 2023). However, in Kazakhstan, these substances' inclusion in the current list of pesticides approved for use in this territory is yet to occur.

The above discussion constitutes the relevance of the presently conducted research. This study aimed to select a protective-stimulating composition for pre-sowing seed treatment in spring wheat and barley against a complex of fungal and bacterial infections and soil pests. Similarly, it seeks for the treatment to stimulate seed germination and root formation with anti-stress activity and resistance to diseases and pests during the growing season.

MATERIALS AND METHODS

Laboratory experiments commenced in the Phytopathology Laboratory, Kazakh Research Institute of Plant Protection and Quarantine named after Zh. Zhiembaev, Almaty, Kazakhstan (KazRIPPQ named after Zh. Zhiembaev).

The wheat cultivar 'Kazakhstanskaya-10' and barley cultivar 'Vakula' seeds' analysis continued to identify the fungal infection according to the methodology of Naumova (1970). The effectiveness of the developed protective-stimulating composition underwent testing on a nutrient medium of a potato-glucose composition (PGC), found acceptable for the growth and development of the fungal and bacterial microflora. Ten of each seed of wheat and barley, placed in a nutrient medium in Petri dishes, had four replications and were 1.0 and 1.5 cm apart to avoid mutual contamination. The cups with wheat and barley seeds, as placed in a thermostat, had a temperature of 24 °C–25 °C. Checking the sowing qualities of wheat and barley seeds followed the standard according to GOST 12044-93 (1993)—agricultural seeds in 50 humid chambers made with plastic containers in 4-fold repetition (Dell'Olmo *et al.,* 2023). Germination energy accounting occurred on the third day, and laboratory germination on the seventh day, by the number of sprouted wheat and barley seeds. At the same time, determining the germination energy and germination of seeds proceeded by the number of sprouted seeds, with the number of moldy and rotten seeds also recorded.

One day before sowing both crop seeds in Petri dishes and plastic containers, the seed material sustained processing in laboratory conditions by manually moistening the seeds with solutions of various protective and stimulating compounds. The used doses selected used 1-channel LLG microdosers (0.5-1000 μl), according to the experimental design. The control had untreated wheat and barley seeds only moistened with distilled water, with acidity (pH) from 5.4 to 6.6.

The use of various compositional combinations in the experiments included the following: a) Scarlet fungicide (tebuconazole, 60 g/l + imazalil, 100 g/l), microemulsion, manufactured by JSC 'Shchelkovo Agrokhim,' Russian Federation (0.4 l/t); b) contact seed protectant Tabu, water-suspension concentrate (imidacloprid 500 g/l), produced by JSC 'Firm

August,' Russian Federation (0.4 l/t); and c) environmentally friendly fertilizer potassium humate (humic acid), liquid, produced by LLC Scientific and Implementation Enterprise 'BashInkom,' Russian Federation (1 l/t). The following treatment combinations used in the experiment were a) Tabu + potassium humate; b) Scarlet + potassium humate; c) Scarlet + Tabu + potassium humate, and d) control (without treatment). Photographs of objects used a camera—Canon EOS-50-D and Redmi-7. The species composition of soil pests, when determined, utilized a Micromed MC var 1-C dissecting stereomicroscope. The species composition of pathogens' determination took place in laboratory conditions using a MicroOptix MX-50 binocular microscope.

In laboratory testing of the protective-stimulating composition against pests, the Chinese beetle *Ulomoides dermestoides* (Chevrolat, 1878) was the pest used to test the objects. The choice of object was due to this species belonging to the darkling beetle family (Tenebrionidae), like many other soil-dwelling pests of grain crops in Kazakhstan. Additionally, it is often the specimen used in similar studies (Temreshev *et al.,* 2019). Individuals of the same age obtained selection for the experiment to avoid their possible premature death from old age. Insects seated in Petri dishes contained grains of barley and wheat treated with protective and stimulating compounds, with 10 specimens in each repetition. The Petri dishes received a seal with a second, larger Petri dish on top to prevent insects from escaping and evaporation of the composition. In the control variant, no seed treatment occurred. The counting of dead insects progressed on the third, fifth, seventh, ninth, and 12th days, as per the rule for testing pesticides in force in Kazakhstan (Temreshev *et al.*, 2025).

The pests' count in the field continued using soil excavations visually, according to Polyakov *et al.* (1984). In determining the species composition and economic importance of soil pests, special keys and other sources obtained from past literature were functional (Guryeva, 1989; Medvedev, 2005), such as 'Insects and mites are pests of agricultural crops' (Skopin, 1961; Nikolaev, 1987). The identification of pathogens (fungi and bacteria) of various plant diseases engaged past literature sources (Bilay, 1977; Blagoveshchenskaya, 2015; Koval *et al*., 2016) and Burgee's bacteria determinant (Khasanov, 1992; Stancheva, 2003; Sokirko *et al*., 2014).

RESULTS AND DISCUSSION

During the phyto-examination of the seeds comprising wheat cultivar Kazakhstan-10 and barley cultivar Vakula, their sowing qualities (germination energy and laboratory germination) and growth intensity, as well as the number of diseased seeds and seedlings, succeeded in recording under laboratory conditions. The phytopathological analysis revealed the numbers of infected seeds with fungal and bacterial infections on nutrient media according to the method of Naumova (1970). The observed incidence of seed-borne pathogens aligns with previous findings by Bateman *et al.* (2018), who emphasized the influence of cultivar-specific resistance on seed infection rates. The results of this study similarly confirm the findings reported by Moumni *et al.* (2023), who expressed the importance of effective seed treatment for controlling seed-borne infections and ensuring healthy plant growth.

The study established that all the analyzed samples of wheat and barley seeds acquired saprophytic and pathogenic microflora infections, dominated by the fungi *Alternaria alternata* (Fr.) Keissl., *Aspergillus niger* Tiegh., *Bipolaris sorokiniana* Shoemaker, *Fusarium avenaceum* (Fr.) Sacc., *F. graminearum* Schwabe, *F. oxysporum* Schltdl., *Microdochium nivale* (Fr.) Samuels & I.C. Hallett, *Mucor mucedo* Fresen., *Penicillium chrysogenum* Thom, *P. glaucum* Link, and bacteria *Erwinia dissolvens* (Rosen, 1922; Burkholder, 1948), *Pseudomonas syringae* (Van-Hall, 1902), and *Xanthomonas campestris* (Pammel, 1895; Dowson, 1939).

The effectiveness of protective-stimulating compositions involved testing in wheat and barley seeds on a nutrient medium of potato-glucose composition (PGC) in humid chambers and in plastic containers in a

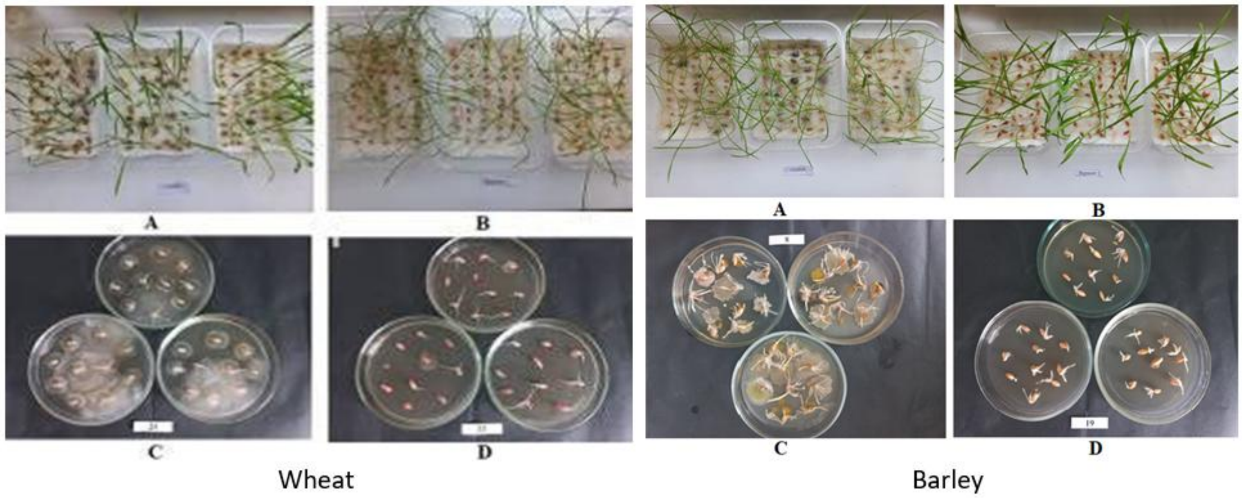

Figure 1. Effectiveness of protective and stimulating compositions in wheat and barley seeds treatment: A, C (before treatment), B, and D (after treatment).

Figure 2. Specimens of the beetle *Ulomoides dermestoides* that died as a result of testing protective and stimulating compositions in wheat (A, B) and barley (C, D) seeds.

humidified way, recommended for the growth of fungal and bacterial microflora (Figure 1). Recent studies have highlighted the importance of selecting appropriate nutrient media for cultivating beneficial microorganisms to enhance seed health. For instance, Garipova *et al.* (2023) demonstrated that the composition of the nutrient medium significantly affects the growth-promoting activity of *Bacillus subtilis* strains, with potato-glucose agar proving effective for wheat inoculation.

The phytopathological analysis revealed the protective-stimulating compositions had a positive effect on cereal seeds (Figures 1 and 2). The treated seed samples of wheat and barley demonstrated significantly higher germination rates, with no evidence of fungal infections. Germination energy assessment occurred on the third day, with the laboratory germination evaluated on the seventh day based on the number of sprouted seeds. Additionally, the intensity of

Table 1. Efficiency of wheat seeds before and after treatment with protective and stimulating compounds (in a humid chamber).

Variants	Germination energy (%)	Seed viability (%)	Growth rate of seedlings (%)			Contamination of seeds (% day)	
			+	++	+++	3rd day	7th day
Tabu + potassium humate	88.5	91.3	13.7	11.5	37.4	4.6	100
Scarlet + potassium humate	85.5	93.3	15.5	6.4	50.5	4.6	72.5
Scarlet + Tabu + potassium humate	99.3	99.3	0.0	0.0	99.3	3.3	3.3
Control	95.3	95.3	9.3	14.6	71.3	15.3	100

Note - + low intensity, ++ medium intensity, +++ intensive development

Table 2. Efficiency of barley seeds before and after treatment with protective and stimulating compounds (in a humid chamber).

Variants	Germination energy (%)	Seed viability (%)	Growth rate of seedlings (%)			Contamination of seeds (% day)	
			+	++	+++	3rd day	7th day
Tabu + potassium humate	80.0	90.6	15.2	6.8	68.6	0.6	68.3
Scarlet + potassium humate	96.0	96.6	0.3	10.0	86.3	0.6	32.0
Scarlet + Tabu + potassium humate	98.0	98.0	0.0	0.6	97.4	1.3	23.3
Control	94.0	94.0	26.2	26.4	42.6	18.6	91.3

Note - + low intensity, ++ medium intensity, +++ intensive development

seedling and root system growth and development was also a consideration (Tables 1 and 2). Similar to the research of Dell'Olmo *et al.* (2023) on leguminous seeds, emphasizing seed health importance for successful plant development, the obtained results demonstrate the protective-stimulating compositions' potential to improve cereal crops' sowing qualities and suppress phytopathogens at early stages. This underscores the overall significance of seed treatment for sustainable crop management.

The highest germination energy and seed viability for wheat and barley seeds were notable in the developed formulation of Scarlet + Tabu + potassium humate (99.3% and 98.0%, respectively). Seed infection rates on the seventh day gave a significant reduction compared with the control. Wheat seeds showed 96.7% lower infection, with barley seeds observed with 76.7% reduction in infection, whereas the control exhibited 100% and 91.3% infection in wheat and barley seeds, respectively. Enhanced seedling growth intensity for both crops was also noticeable under this treatment, unequivocally demonstrating the considerable fungicidal properties of the developed protective-stimulating composition. The substantial reduction in seed infection and enhanced germination observed with the developed formulation echoes the findings of Goulart (2022), who exhibited the effectiveness of fungicide seed treatment in controlling damping-off in soybeans caused by *Rhizoctonia solani*. While their study focused on a different pathogen and crop, it underscores the general principle that targeted seed treatments can effectively suppress soilborne and seedborne pathogens, leading to improved seedling establishment and overall plant health.

By testing the effect of various variants of protective-stimulating compositions on the darkling beetle *Ulomoides dermestoides*, their biological effectiveness against the pest received attention (Figures 2 and 3). The results obtained in the laboratory tests of protective-stimulating compounds against the darkling beetle *U. dermestoides* on wheat and barley seeds appear in Tables 3 to 5. The results of laboratory tests confirm that the effectiveness of protective-stimulating

Figure 3. Live specimens of the beetle *Ulomoides dermestoides* in wheat (A) and barley (B) seeds in the control.

Table 3. Effectiveness of the variant Scarlet + Tabu + potassium humate in wheat and barley seeds against the *Ulomoides dermestoides* beetle.

Repeatability (10 specimens)	Experiment						Control					
	1st day	3rd day	5th day	7th day	9th day	12th day	1st day	3rd day	5th day	7th day	9th day	12th day
Wheat												
1	10	8	4	2	0	0	10	10	10	10	10	10
2	10	8	2	1	1	0	10	10	10	10	10	10
3	9	5	4	2	1	0	10	10	10	10	10	10
4	10	5	4	2	0	0	10	10	10	10	10	10
Barley												
1	10	8	8	4	2	0	10	10	10	10	10	10
2	9	5	5	5	0	0	10	10	10	10	10	10
3	9	6	5	2	0	0	10	10	10	10	10	10
4	10	9	8	6	2	0	10	10	10	10	10	10

Table 4. Effectiveness of the variant Tabu + potassium humate in wheat and barley seeds against the *Ulomoides dermestoides* beetle.

Repeatability (10 specimens)	Experiment						Control					
	1st day	3rd day	5th day	7th day	9th day	12th day	1st day	3rd day	5th day	7th day	9th day	12th day
Wheat												
1	10	2	4	1	0	0	10	10	10	10	10	10
2	10	4	0	0	0	0	10	10	10	10	10	10
3	9	4	2	1	0	0	10	10	10	10	10	10
4	10	4	3	1	0	0	10	10	10	10	10	10
Barley												
1	9	6	5	4	0	0	10	10	10	10	10	10
2	9	4	4	3	1	0	10	10	10	10	10	10
3	9	6	5	4	1	0	10	10	10	10	10	10
4	10	4	4	2	1	0	10	10	10	10	10	10

Table 5. Effectiveness of the variant Scarlet + potassium humate in wheat and barley seeds against the *Ulomoides dermestoides* beetle.

Repeatability (10 specimens)	Experiment						Control					
	1st day	3rd day	5th day	7th day	9th day	12th day	1st day	3rd day	5th day	7th day	9th day	12th day
Wheat												
1	10	9	9	9	9	8	10	10	10	10	10	10
2	10	10	10	10	10	9	10	10	10	10	10	10
3	10	10	10	10	10	10	10	10	10	10	10	10
4	10	10	10	10	10	10	10	10	10	10	10	10
Barley												
1	10	9	8	8	8	8	10	10	10	10	10	10
2	10	9	9	9	9	9	10	10	10	10	10	10
3	10	10	10	10	10	10	10	10	10	10	10	10
4	10	10	10	10	10	10	10	10	10	10	10	10

compositions can vary significantly depending on the type of seed material and the formulation of the compound. The most active substances demonstrated pronounced insecticidal activity, comparable to the results obtained by other researchers using plant extracts against Tenebrionidae under grain storage conditions (Abdel-Rahman, 2019; Ghosh, 2021). This highlights the potential of botanical products as an environmentally safe alternative to synthetic insecticides.

The presented data analysis and compilation revealed the combination of Tabu with potassium humate exhibited the highest efficacy, followed by the triple treatment of Scarlet, Tabu, and potassium humate. The Scarlet in combination with potassium humate treatment displayed comparatively lower effectiveness. In the untreated control group of the wheat and barley seeds, the beetle population remained essentially stable throughout the experimental period. The significant reduction in *Ulomoides dermestoides* infestation observed with the developed protective-stimulating compositions highlights the potential of such formulations as alternatives to conventional insecticides in stored grain protection. This aligns with findings by Islam (2020), who reported the bio-efficacy of plant extracts against this pest in stored wheat, with further support from Ghosh (2021), who evaluated plant-based biopesticides against a range of stored grain pests, including potentially *Ulomoides dermestoides.*

CONCLUSIONS

The developed protective-stimulating composition (Scarlet, m.e., 0.4 l/t + Tabu, w.s.c., 0.4 l/t + potassium humate, liquid, 1.0 l/t) offers multiple advantages. It significantly enhances efficacy against fungal and bacterial infections on the wheat and barley seeds' surface and internally. The said formulation stimulates germination energy and seed viability and promotes growth and development of the wheat and barley seedlings and root systems with reduced infection rates. The protective-stimulating composition effectively prevents seed-borne diseases and diminishes their impact during the vegetation period, simultaneously increasing plant resistance to soil-dwelling pests. Additionally, the composition was cost-effective and contributes to reduced environmental impact of the pesticide due to its low application rates.

ACKNOWLEDGMENTS

Scientific research proceeded within the framework of the budget program 267, 'Increasing the Availability of Knowledge and Scientific Research and Activities,' under the scientific technical program BR22887166, 'Integrated Pest Management System.'

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