

ABSTRACT

for the dissertation of Pavel Lushchak entitled: “Development of Adaptive Practices to Increase Productivity and Drought Resistance of Bread Wheat in the Dry Steppe Zone of Central Kazakhstan” submitted for the degree of Doctor of Philosophy (PhD) in the educational program 8D08102 – Organic Agriculture

Wheat is a key agricultural crop that ensures global food security and provides about 20% of the world's caloric intake.

At present, Kazakhstan is a major producer of wheat and one of the leading grain exporters in the global market. Over the past 20 years, wheat production in the Republic of Kazakhstan has ranged from 8.36 to 26.7 million tons annually, of which 3.4 to 9.1 million tons of grain and 0.6 to 2.0 million tons of flour are exported. The main share of exports is directed to Central Asian countries. The proportion of wheat exports is characterized by high variability and ranges from 20% to 65% of annual production.

Wheat is the dominant agricultural crop in the country in terms of sown area, accounting for about 80% of total grain production. The wheat cultivation area ranges from 10.74 to 13.81 million hectares, with a significant share (around 17.5 million hectares in 2020) located under rainfed conditions in Central and Northern Kazakhstan. However, despite the extensive areas devoted to wheat, yields remain below regional and global averages. The long-term average wheat yield in Kazakhstan is 10.9 centners per hectare.

The main limiting factors of low productivity are the climatic conditions of Kazakhstan's grain-growing regions (a short growing season, high temperatures during vegetation, and limited moisture availability), as well as the low level of input use (fertilizers and plant protection products). This significantly constrains the yield potential of spring bread wheat and leads to considerable year-to-year yield variability.

The climate of Central Kazakhstan is characterized predominantly by arid and severely arid moisture regimes, placing additional stress on agroecosystems. The strong dependence of grain production on weather conditions is confirmed by statistical data, which show high yields in favorable years (2011, 2024) and sharp declines during drought periods (2010, 2023).

Numerous field studies indicate that the increasing frequency of droughts in Kazakhstan has led to a significant decline in wheat yields, especially in recent years. According to R. Kumar (2021), climate-induced droughts observed in the country result in a 10-30% reduction in grain crop yields.

Mitigating the impacts of climate change remains one of the key challenges in the major grain-producing regions of Kazakhstan. One of the most effective strategies to reduce the negative effects of drought on wheat is the adaptation of existing agrotechnological practices at the crop management level.

In this regard, improving the technological practices for cultivating spring bread wheat in order to enhance its drought resistance and productivity is a highly relevant task and of significant practical importance for the dry steppe zone of

Central Kazakhstan. Such approaches enable the most efficient use of available agrobiological resources.

The modification of agrotechnological practices – including the selection of stress-tolerant varieties, the application of moisture-conserving tillage methods, and the use of techniques to stimulate plant growth and development – is considered a dynamic long-term strategy for mitigating drought-related stress.

The aim of the research is to develop a set of agrotechnical measures to improve the drought resistance and productivity of spring bread wheat under the sharply continental, arid soil and climatic conditions of Central Kazakhstan using mathematical modeling methods.

The objectives of the research include:

- to identify more drought-resistant varieties of spring bread wheat using genotyping methods based on SNP markers;
- to develop optimal parameters of комплексных стимулирующих средств (complex growth-stimulating treatments) for the studied varieties of spring bread wheat to enhance their drought tolerance;
- to study and determine the effectiveness of various growth stimulants in the cultivation of spring bread wheat in the dry steppe zone of Central Kazakhstan;
- to establish the effect of surface soil tillage on yield formation and drought resistance of spring bread wheat varieties under arid conditions of Central Kazakhstan using mathematical modeling;
- to assess yield formation and drought resistance levels of the studied spring bread wheat varieties based on simulation modeling;
- to determine the economic efficiency of the recommended cultivation practices for spring bread wheat, taking into account the soil and climatic conditions of Central Kazakhstan.

Research methods.

The study employed a комплексный (comprehensive) set of methods, including field experiments and laboratory analyses to evaluate the impact of agrotechnical practices on wheat productivity and drought resistance. Molecular genetic methods (SNP genotyping) were used to identify resistant genotypes, along with statistical data analysis. Mathematical modeling was also applied to predict yield depending on environmental conditions and applied technologies.

Statistical processing of the research results was carried out using analysis of variance (ANOVA) with the software packages Microsoft Excel 2010 and Statistica 8.0. The calibration and validation of the spring soft wheat variety model was carried out using the STICS-24 program.

Main provisions submitted for defense:

- the theoretical and experimental substantiation of optimal parameters for the use of complex stimulating agents that increase the intensity of growth processes and realize the productive potential of spring wheat varieties identified based on the results of genotyping.
- patterns of yield formation and the main elements of the crop structure of spring soft wheat varieties, depending on the complex of applied agrotechnical measures, including the use of complex stimulating agents.

- a scientifically based model of drought-resistant varieties of spring soft wheat adapted to the conditions of the dry steppe zone of Central Kazakhstan, as well as an assessment of the economic efficiency of the introduction of the developed technological methods of its cultivation.

Description of the main research results.

1. As a result of molecular genetic screening of 11 spring bread wheat varieties recommended for cultivation in the Republic of Kazakhstan, genotypes with single nucleotide polymorphisms in key genes associated with drought resistance (TaDr1B, DREB1, TaPARG-2A, TaPPH-7A, COMT3B) were identified. The absence of polymorphism in the TaLTP gene and monomorphism in the 1fhw3 gene were also established. The most favorable allelic combination associated with drought tolerance was identified in the Taimas and Granny varieties, which were selected for further field studies and recommended for cultivation under arid conditions of Central Kazakhstan.

2. It was established that the application of a комплексное средство (combined treatment), including microelements (Zn, Mn, Cu, Fe, Si), a polysaccharide (sodium alginate), and a phytohormone (24-epibrassinolide), significantly increases laboratory seed germination – from 67.14-68.48% to 92.47-92.67% – as well as improves root system development and increases germination index (GI) and seedling vigor index (SVI). Under simulated drought conditions, hydrotropism was observed in wheat seedlings, accompanied by a decrease in root growth angle. The use of optimal concentrations of the combined treatment further reduced this parameter and improved the adaptive characteristics of plants.

Correlation analysis revealed a strong relationship between seedling growth parameters (shoot length, root mass, and root length), especially under moisture deficit conditions. The results of the analysis of variance confirmed a statistically significant effect of the variety, germination conditions, and seed treatment on germination indicators.

3. Field studies showed that the application of combined treatments increases field germination of the Taimas variety by 2.4-5.0%, regardless of the cultivation zone. The yield of spring bread wheat is largely determined by the interaction of the variety genotype, agrotechnological practices, and weather conditions of the year.

4. The maximum yield values (31.44 c/ha in 2023 and 42.5 c/ha in 2024) were obtained with the integrated application of agrotechnological practices, including pre-sowing seed treatment, the use of combined treatments, and surface soil tillage. Under the conditions of Naydorovskoye LLP, the Taimas variety demonstrated a higher average yield (30.9 c/ha), exceeding the Granny variety by 2.18 c/ha. It was established that under arid conditions, yield formation depends on a комплекс (set) of structural elements (1000-grain weight, number of grains per spike, productive tillering), whereas in wetter years, plant density and grain weight become decisive factors.

Analysis of variance showed that the greatest influence on yield formation is exerted by:

- the wheat variety genotype (37.73–41.17%);

- seed and crop treatment with complex formulations (17.07–18.71%);
- surface soil tillage (11.09–12.46%).

The highest actual yield (up to 34.55 c/ha) was obtained in the treatment variant that included seed treatment with a complex formulation, foliar feeding at the tillering stage, as well as rolling and harrowing of the crops.

5. The results of simulation modeling confirmed a strong dependence of yield on the interaction of the factors “genotype – environment – technology.” It was established that the Taimas variety is characterized by higher stability and drought resistance compared to the Granny variety, as evidenced by the values of stability indices (STI, DI, SSI) and model coefficients ($R_x = 0.87-0.93$).

The optimal cultivation model of spring bread wheat under arid conditions includes pre-sowing seed treatment with complex microelements, foliar feeding at the tillering stage, as well as agrotechnical practices (rolling and harrowing), ensuring the most complete realization of the biological potential of plants. The obtained results confirm the high effectiveness of the developed комплекс агротехнологических мероприятий for improving the productivity and drought resistance of spring bread wheat under the conditions of Central Kazakhstan.

6. Treatment of seeds and crops with a complex stimulating agent, as well as surface tillage of spring wheat crops, increases the tolerance index (3.01-3.17 units), drought resistance (5.71-8.04 units), stress resistance (1.24 - 1.81 units) and provides high stability (up to 24.73%) and reliability (0.91 units). in the conditions of Naydorovskoye LLP, Osakarovsky district, Karaganda region.

7. The application of the developed model of spring soft wheat cultivation in the conditions of Naydorovskoye LLP with seed treatment with a complex stimulating drug and the use of leaf fertilizers in combination with rolling after sowing allows for consistently high crop yields ($R_x = 0.87-0.93$) and economic efficiency of production by reducing the cost of grain to 48.37 thousand tenge per year. per ton, which contributes to an increase in profitability to 111.58%.

The objects of the study were 11 mid-season spring bread wheat varieties included in the register of breeding achievements recommended for use in the Republic of Kazakhstan, as well as a complex treatment aimed at improving seed germination, plant drought resistance, and productivity.

Scientific novelty of the study.

The most effective elements of technological methods for cultivating spring soft wheat have been developed, increasing productivity and drought resistance in the dry-steppe zone of Central Kazakhstan, and optimal parameters for the use of a complex stimulating agent have been established to maximize the productivity of spring soft wheat.

Compliance with scientific development priorities or state programs.

The work was carried out within the framework of grant funding for scientific and (or) scientific-technical projects for 2022–2024 by the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan: AP14870923 “Development of adaptive practices to increase productivity and drought resistance of bread wheat under arid conditions of Central

and Northern Kazakhstan using mathematical modeling,” state registration No. 0122RK00548.

Doctoral student’s contribution to the preparation of publications.

Based on the research results, 8 scientific publications were issued, including two articles published in international journals indexed in the Web of Science and Scopus databases.

1. Lutschak P., Amantayev B., Kipshakbayeva G., Stybayev G., Zargar M., Ebzeev D., Soltani Nejad M. Enhancing drought resistance in early-stage development of spring soft wheat (*Triticum aestivum* L.) using trace elements in a dry steppe zone. *Research on Crops* 25 (3): 394-402 (2024). <https://doi.org/10.31830/2348-7542.2024.ROC-1092>. (Scopus, Cite Score -38, Q3)

2. Amantayev B., Kipshakbayeva G., Turbekova A., Kulzhabayev Y., d Lutschak P. Enhancing Drought Resistance in Spring Wheat (*Triticum aestivum* L.) Through Chelated Zinc Seed Treatment: An Experimental Study. *OnLine Journal of Biological Sciences* 2025, 25 (1): 53-64. <https://doi.org/10.3844/ojbsci.2025.53.64>. (Scopus, Cite Score -54, Q2).

Three articles were published in journals recommended by the Committee for Quality Assurance in the Sphere of Science and Higher Education (CQASHE) of the Ministry of Science and Higher Education of the Republic of Kazakhstan:

1. Amantaev B.O., Kipshakbayeva G.A., Kulzhabayev E.M., Lushchak P.V. “Effect of drought on germination indicators of spring wheat varieties.” *Bulletin of Science of S. Seifullin Kazakh Agro Technical Research University, Astana*. 2023. No. 3(118), pp. 181-192.

2. Lushchak P., Amantaev B.O., Meisam Zargar, Kipshakbayeva G.A., Stybayev G.Zh., Kulzhabayev E.M. “Application of phytohormones to reduce the negative effects of drought at the initial developmental stages of spring bread wheat varieties.” *Bulletin of Korkyt Ata Kyzylorda University*. No. 2 (69), 2024, pp. 140-150.

3. Amantaev B.O., Kipshakbayeva G.A., Meisam Zargar, Kulzhabayev E.M., Kashkarov A.A., Lushchak P.V., Karimova A.M. “Integrated agrotechnological measures to improve productivity and drought resistance of spring bread wheat varieties.” *Bulletin of Science of S. Seifullin Kazakh Agro Technical Research University, Astana*. 2025. No. 2 (125), pp. 30-39.

Based on the results of the research work, a utility model patent was obtained for the invention “Complex formulation and treatment method for stimulating the growth and development of wheat” No. 10033 (authors: Amantaev B.O., Kulzhabayev E.M., Lushchak P.V.; registration date – 13.05.2024).

The main provisions of the dissertation were presented and published in the proceedings of scientific and practical conferences:

1. XIX International Scientific and Practical Conference “World Science Priorities”, November 20–21, 2025, Vienna, Austria. Topic: “Kazakhstan: Genotyping of wheat varieties using SNP Amplifluor markers for drought tolerance.”

2. XXI International Scientific and Practical Conference “Scientific Advances and Innovative Approaches”, February 26–27, 2026, Tokyo, Japan.

Topic: “Economic efficiency of spring wheat cultivation depending on various agrotechnological measures.”