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SPRING SOFT WHEAT (*TRITICUM AESTIVUM* L.) BREEDING: ANALYTICAL REVIEW

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SUMMARY

Kazakhstan is a major wheat (*Triticum aestivum* L.) producer, with a planting area of 12–14 million hectares, and ranks third in the Commonwealth of Independent States (CIS) market for grains and flour production. In the future, Kazakhstan could produce more than 10 million tons of wheat, equivalent to the combined wheat production of Central Asia, Afghanistan, and the European Union. The following research aimed to identify methodological aspects comprising the development of the ideotypes (non-irrigated, dry steppe, and intensive) and new spring soft and perspective lines of wheat cultivars with a complex of valuable traits. The research source material was the spring wheat cultivars and hybrids and advanced lines. The establishment of spring wheat nurseries, records and observations, hybridization, evaluation, and statistical compilation of the recorded data proceeded using methodologies developed through domestic and foreign sources. Overall, the study identified the methodological aspects and research work directions and developed ideotypes and 29 cultivars of spring wheat and two cultivars of facultative soft wheat, approved for use in production in Kazakhstan, Kyrgyzstan, and Russia. Promising lines of soft spring wheat have succeeded in their identification for further breeding work. New varieties and promising lines are also new sources of valuable traits and properties for breeders and geneticists.

Keywords: Wheat (*T. aestivum* L.), breeding, cultivars and advanced lines, valuable traits, growing seasons, disease resistance, grain yield and quality

Key findings: The identification of methodological aspects about the wheat (*T. aestivum* L.) breeding was successful, as well as the development of ideotypes, 29 spring wheat, and two facultative soft wheat cultivars, which also reached approval for use in production in Kazakhstan, Kyrgyzstan, and Russia. Moreover, they are sources of valuable traits and properties for work in wheat breeding and genetics.

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is the leading staple food crop, requiring improvement in its productivity to meet the food demand of the global population (Long *et al.*, 2015). Kazakhstan is a major wheat producer, with a sowing area of 12–14 million hectares, with its grains considered as the country's national brand. In the near future, Kazakhstan could produce more than 10 million tons of grain, equivalent to the combined wheat production of Central Asia, Afghanistan, and the EU. For enhanced productivity, one of the best approaches is to develop high-yielding soft spring wheat cultivars with better quality and climate resilience. This is because crop yields primarily depend on the genetic makeup of genotypes (Pleskachev *et al.*, 2019; Voronov *et al.*, 2020). Globally, crop losses due to droughts and heatwaves in Europe have tripled over the past 50 years, ranging from 2.2% (1964–1990) to 7.3% (1991–2015) (Bras *et al.*, 2021).

Climate change and wheat production forecasts revealed temperatures will rise by 1.07 °C by 2045 (Djanaguiraman *et al.*, 2020). The Food and Agriculture Organization (FAO), United Nations, recommended implementation of a climate-optimized approach to agriculture by developing well-adapted and stress-resistant crop cultivars (FAO Climate-Optimized Agriculture, 2021). Moreover, due to rapid population growth and climate change, it is imperative to increase the rate of annual improvement in the genetic yield potential of agricultural crops, which varies from 0% to 1.23%, to meet global demands (Li *et al.*, 2018).

Previous studies enunciated that in worldwide spring soft wheat breeding, such basic traits as productivity (Friedrich and Longin, 2016a), grain quality (Fradgley *et al.*, 2023), drought resistance (Mohammadi, 2018; Tshikunde *et al.*, 2019), earliness (Dorrani *et al.*, 2022), disease resistance (Babu *et al.*, 2020), and hybrid breeding (Friedrich and Longin, 2016b) remain unchanged. The research work mainly used classical breeding methods such as the collection, screening, and utilization of wheat germplasm (Rajaram,

2001); hybridization (Sandhu *et al.*, 2021); and evaluation and improvement through selection of genotypes with desirable traits, as well as methodological recommendations from related biological sciences (Alam *et al.*, 2024).

The same breeding approaches are applicable in the selection of spring soft wheat in Kazakhstan. One of the problems is the development of early-maturing cultivars in spring wheat, which is an issue since ripening happens 3–4 days earlier than mid-early cultivars. Given that optimized grain production has an association with the cultivation of wheat cultivars of different ripeness (Mohammadi, 2018; Pleskachev *et al.*, 2019). The next direction is the development of drought-resistant cultivars, where in Kazakhstan, drought occurs at different times of the growing season and with varying degrees of intensity. The development of salt-resistant wheat cultivars stems from the fact that Kazakhstan has vast areas of saline and saline-alkaline soils.

The breeding of spring wheat cultivars that are resistant to diseases and pests with the highest grain technological properties is a constant priority in breeding research. It is also vital for the research on the selection and development of facultative wheat cultivars, a greater interest in growing conditions of southern and southeastern Kazakhstan (Nurpeisov and Yerzhebayeva, 2009; Nurpeissov, I.A., Kushanova, R. Zh 2025). Unlike typical spring and winter cultivars, sowing optional wheat cultivars can continue in autumn or spring (Keser *et al.*, 2020). These cultivars were especially indispensable in regions with mild climates in winter, where sowing dates require adjustment for organizational and production reasons. This is because the dry soil and climatic conditions in autumn quite often occur in the south and southeast of Kazakhstan (Nurpeisov, 2019).

In spring wheat breeding, the main priority is yield, as determined by the influence of the above-mentioned varied characteristics. Therefore, the consequent research aimed to identify methodological aspects comprising the development of the ideotypes and new spring soft wheat cultivars with a complex of valuable traits.

MATERIALS AND METHODS

The research source material was the cultivars, hybrids, and perspective lines of spring soft wheat (*T. aestivum* L.). The conducted experiments took place in irrigated fields located in the foothills (800–1200 m above sea level, precipitation at 350–500 mm per year, and total active temperatures of 2700 °C–32000 °C), as well as in an arid dry steppe zone (600 m above sea level, precipitation at 180–200 mm per year, and total active temperatures of 3400 °C–40000 °C) in the Almaty Region, Kazakhstan. Ecological variety testing (EVT) of promising genotypes mostly continued in the south, east, and west, as well as in the central and northern regions of Kazakhstan. Hybridization work used the N. Barlaug method, modified by Urazaliev and Shegebaev (1981).

Phenological observations

Breeding material evaluation followed the State Variety Testing Methodology (2002), and the establishment of nurseries used generally accepted breeding methods. The standard varieties approved for use in production in the Republic of Kazakhstan were Kazakhstanskaya 4, Arai, Kazakhstanskaya 10, and Kazakhstanskaya rannespelaya.

Immunological evaluation of breeding materials for resistance to diseases and pests proceeded according to Koishibaev and Mumindzhanov (2016). Assessing the degree of plant damage utilized Peterson *et al.*'s (1948) scale, and evaluating the type of reaction to rust damage employed the SIMMIT scale (Stubbs *et al.*, 1986).

The drought resistance of spring soft wheat lines assessment was on 10–12-day-old seedlings using the Barr and Weatherley (1962) method. Identification of high-molecular-weight glutenin subunits (HMGW) was according to the catalog of Nurpeisov *et al.* (2008).

Statistical analysis

The data statistical compilation performed by the study used the open-source program R

(version 3.2.3 [2015-12-10]—Wooden Christmas-Tree, 2021). Standard parametric tests and analyses continued, with statistical significance determined using built-in and additional packages (dplyr, ggplot2, and psych). The combinatorial ability analysis in wheat took place according to Griffing (1956) and Wolf and Litun (1980).

RESULTS AND DISCUSSION

Research studies

The Eastern Selection Center at Kazakh Scientific Research Institute of Agriculture developed a long-term selection program called 'Ak Bidai' in 1983, which aimed to carry out effective evaluation and selection and application of genetic approaches to develop high-yielding spring wheat (*T. aestivum* L.) cultivars (Sariev *et al.*, 1983). Thus, the review comprised the study of the VIR world collection accessions and elite lines across different ecological zones, materials from the State Variety Testing Commission, and varietal mixtures cultivated without selection under diverse conditions. It also included the dynamics of hybrid population development under various soil and climatic conditions and the comparison of lines derived from the same populations at different locations, where ideotypes of spring wheat for different cultivation conditions have reached development. In particular, the developed ideotypes of spring wheat for various cultivation conditions consisted of non-irrigated lands in the southeastern region, non-irrigated lands in the dry steppe zone, and an ideotype for cultivation on irrigated lands in Kazakhstan. Bannikov (1966) discussed the economic traits of wheat collection samples on two sharply contrasting backgrounds (irrigation and bogara) and also identified forms found valuable for breeding work.

In hybrid wheat, new fertility restorers and sterility fixers reached identification and development, as well as F1 hybrids with the highest level of heterotic effects in terms of 1000-grain weight and grain weight per ear. The authentication of fertility restoration

revealed its control by at least 2–3 genes acting cumulatively with unequal dominance. Evidently, it was advisable to carry out research work on obtaining wheat hybrids based on cytoplasmic male sterility in the winter sowing of spring wheat under the conditions of the Almaty Region, Kazakhstan (Esimbekova, 1987).

Past studies also detailed that it was impossible to develop hybrids from several cross combinations with the presence of hybrid necrosis in the parental cultivars of spring wheat. The 35 wheat genotypes carrying hybrid necrosis genes have entailed identification and regionalization in Kazakhstan and 233 samples from the VIR world collection. Replacing cultivars carrying hybrid necrosis genes with their analogs free of these genes will further prevent the spread of these harmful genes (Pereyaslova, 1983).

The success of spring wheat breeding research primarily depends on working with the hybrid populations, which ensures the selection and development of desired forms. One has also established that the level of F1 heterosis cannot serve as a criterion for determining the breeding value of cultivars and their hybrid combinations. However, the F3–F4 hybrid populations that exceed their parental forms in economically valuable traits were of practical interest (Abugaliev, 1981).

Several productive cultivars and mutants of spring wheat have succeeded in their selection as parental genotypes based on their combining ability to enhance grain yield (Seksenbaeva, 1978). For improving the setting rate of hybrid grains in interspecific crosses, effective methods have been notable, determining the combining ability of VIR durum wheat cultivars based on economically valuable traits (Borambaev, 1981). The establishment of wheat species with the same number of chromosomes that can be easily crossed with each other to produce fertile offspring was successful. For enhancement in the number of grains per ear, the recommendation was to use the species *Triticum turgidum* and *Triticum aethiopicum*. The species *Triticum turanicum* emerged as recommendable for use as a potential source for increasing the 1000-grain weight, while the recommendation of species

Triticum persicum occurred for obtaining effective forms of immunity to powdery mildew and brown rust (Zhangaziev, 2010).

The development of a series of monosomic lines of the Kazakhstan-126 variety used cytogenetic research methods. The presence of a gene modifier for the awnless trait in chromosome 6D entailed establishment, with the ear color gene Rg3 in chromosome 6A and the plant height gene Rht10 in chromosome 7A localized in wheat. Previous studies on spring wheat also confirmed the control of genes located on chromosomes 5A and 5D on growing season duration and maturity. In the developed series of monosomic lines, the homozygosity was evident after the ninth and tenth backcrosses (BC9 – BC10) (Shulembaeva, 1983). In wheat, sources, and donors of frost tolerance, vegetation period duration, and quantitative traits were distinguishable; selection criteria for productivity reached refinement; and development of new hybrid populations and promising lines for further breeding work succeeded (Nurpeisov, 2006). Sources of resistance to yellow rust (Nurpeisov *et al.*, 2007) and earliness (Yessenbayeva, 2009) were noteworthy, and the breeding value of varieties and breeding lines obtained through intraspecific, interspecific, and distant hybridization incurred evaluation (Stepanov and Nurpeisov, 2008; Nurpeisov and Yezhebayeva, 2009).

The manifestation of contrast in spring wheat with trait variability has gained identification in different ecological zones (Baimagambetova, 2010). A study established that the OSP (one seed per plant for offspring) selection method appeared not extensive; however, it was more effective than comparable methods of selection in mass reseeding (MP). Therefore, it was necessary to conduct selection in populations selected according to a set of indicators at various ecological points (Novokhatin, 2016).

Breeding research

Breeding work on spring soft wheat in Southeastern Kazakhstan began in 1935 at the Almaty Breeding Station. Using mass selection

methods from local populations of spring soft wheat, the varieties Grekum 239, Grekum 283, Grekum 433, Albidum 22808, and Krasnaya Zvezda attained development. Starting from the 1940s, hybridization with the involvement of the gene pool of local populations and accessions from the world collection gained wide usage in the breeding program. As a result, the creation of a spring soft wheat variety, Kazakhstanskaya 126, was successful. Later, in 1965–1980, intensive varieties of this crop continued to develop: Kazakhstanskaya 3, Kazakhstanskaya 4, and Erythrospermum 74. Issues related to vegetation period, drought and salinity tolerance, pest and disease resistance, grain quality, facultative growth habit, and wheat yield received attention through developing a series of new varieties adapted to specific conditions of the RK, KR, and RF.

Based on the long-time research, more than 75 cultivars of spring soft wheat entailed production. Among them, numerous spring soft wheat cultivars have attained approval for use in production in the Kazakhstan. These are Kazakhstanskaya rannespelaya, Kazakhstanskaya 4, Kazakhstanskaya 15, Kazakhstanskaya Kazakhstanskaya 17, Kazakhstanskaya 19, Kazakhstanskaya 25, Lutescens 32, Lutescens 90, Zhenis, Arai, Miras, Nadezhda, Alem, Aktobe 39, Almaken, Stepnaya 50, Samgau, Oskemen, Tabys 60, and Bolashak. Similarly, optional cultivars Kazakhstanskaya 10 and Yegemen surfaced (State Register of Breeding Achievements recommended for use in the Kazakhstan, 2024, No. 34351). The spring wheat cultivars Rakanzam, Samad, Shapagat, Aikyn 58, Zhiger 2014, Kazakhstan 75, Oskemen, and Kazakhstan 10 attained regionalization in the Kyrgyzstan (State Register of Plant Cultivars and Hybrids approved for use in the Kyrgyzstan, 2018). The soft spring wheat cultivars Lutescens 70, Ilyinskaya, SKENT-3, Ikar, Kazakhstan Rannespelaya, and Kazakhstan 10 succeeded in being zoned in the Russian Federation. The brief description of a number of spring and facultative wheat cultivars regionalized in the Kazakhstan, Kyrgyzstan, and the Russia during 1991–2023 is available in Table 1.

Among the above spring soft wheat cultivars, Kazakhstanskaya 4, Kazakhstanskaya 10, Arai, Zhenis, Alem, Nadezhda, Miras, Almaken, Tabys 60, and Bolashak emerged for cultivation in the south and southeast of Kazakhstan. The other cultivars served the northern, western, and eastern regions of the country. These cultivars were considerably different in intensity, ripeness, resistance to stressful environmental conditions, diseases, and pests, forming the robust and valuable wheat grains. Consequently, these genotypes can also be beneficial as sources of economically valuable traits and properties in wheat breeding. For example, the cultivars Kazakhstanskaya rannespelaya, Kazakhstanskaya 4, Kazakhstanskaya 17, Lutescens 32, and Miras showed characteristics for early maturity. The cultivars Kazakhstanskaya rannespelaya, Kazakhstanskaya 4, Kazakhstanskaya 15, Kazakhstanskaya 19, Samgau, Alem, Stepnaya 50, Zhenis, Oskemen, Aktobe 39, and Bolashak were distinct for their drought resistance and resistance to lodging.

The spring soft wheat cultivars Lutescens 70, Lutescens 90, and Kazakhstanskaya 15 emerged as resistant to pre-harvest sprouting of grains on the stalk. The cultivar Kazakhstanskaya 10 was a facultative wheat, with low sensitivity to low temperatures, salt tolerance, and resistance to lodging. The facultative cultivar Yegemen has features of the highest iron and zinc content in the grains. The cultivars Kazakhstanskaya rannespelaya, Kazakhstanskaya 4, Kazakhstanskaya 15, Kazakhstanskaya 17, Kazakhstanskaya 19, Kazakhstanskaya 25, Lutescens 32, Lutescens 90 Oskemen, and Aktobe 39 meet the requirements of GOST for robust wheat, while the remaining cultivars meet the requirements for valuable wheat. The cultivars Kazakhstanskaya 10, Kazakhstanskaya 19, and Lutescens 90 showed group resistance to yellow and brown rust.

New spring soft wheat cultivars, such as Oskemen, Tabys 60, and Bolashak, attained approval for production in 2017, 2019, and 2023, respectively. In the competitive variety testing nursery (CVT), these cultivars' grain

Table 1. Approved for use for production in the Kazakhstan, Kyrgyzstan, and Russian Federation during 1991–2023.

Cultivars	Country and year of approval	Variety characteristics		
		Ripeness type	Grain and flour quality	Yield and other economic indicators
Kazakhstan rannespelaya	Kazakhstan and Russian Federation - 1991	Early Ripening	Strong	Average yield on non-irrigated land is 2.1 t/ha. Resistant to drought and ear shattering during overgrowth.
Kazakhstan 10 – <i>facultative variety</i> .	Russian Federation and Kyrgyzstan - 1992	Medium Late	Valuable	Facultative variety. Maximum yield on irrigated land for autumn and spring sowing is 4.5 and 3.6 t/ha, respectively. Cold-resistant, salt-tolerant, resistant to lodging.
Kazakhstan 17	Kazakhstan - 1994	Early Ripening	Strong	Maximum yield on non-irrigated land is 3.6 t/ha. Resistant to lodging and brown rust.
Lutescens 32	Kazakhstan - 1996	Early Ripening	Strong	Average yield on irrigated land is 3.5 t/ha and on semi-irrigated land is 2.3 t/ha. Resistant to yellow rust.
Lutescens 90	Kazakhstan - 1996	Medium ripening	Strong	Maximum yield on irrigated land is 4.1 t/ha. Resistant to grain sprouting on the root and rust.
Arai	Kazakhstan - 1999	Medium ripening	Valuable	Maximum yield on irrigated land is 3.7 t/ha. Resistant to smut and yellow rust.
Egem- <i>facultative variety</i> .	Kazakhstan - 2006	Medium ripening	Valuable	The average yield for autumn sowing reaches 4.1 t/ha and for spring sowing - up to 2.5 t/ha. The grains of this variety contain high levels of iron and zinc.
Almaken	Kazakhstan - 2011	Average ripening	Valuable	Average yield on non-irrigated land is 3.5 t/ha. Resistant to grain shattering and ear lodging, moderately resistant to rust diseases.
Stepnaya 50	Kazakhstan - 2011	Medium ripening	Strong	Average yield on non-irrigated land is 2.3 t/ha, resistant to drought and spillage of ears during overgrowth.
Oskemen	Kazakhstan - 2017	Medium ripening	Valuable	Average yield on irrigated land is 3.2 t/ha and on non-irrigated land is 2.4 t/ha. Resistant to brown rust and drought.
Tabys 60	Kazakhstan - 2019	Medium ripening	Valuable	The average yield of the Tabys 60 variety under irrigation is 4.1 t/ha and under dry farming 3.0 t/ha; exceeding standards by up to 0.5 t/ha.
Bolashak	Kazakhstan - 2023	Average mature	Valuable	The average yield of the Bolashak variety is 4.0 t/ha on irrigated land and 2.9 t/ha on semi-irrigated land. Resistant to drought and dusty smut .

yield ranged from 3.0 to 4.1 t/ha on irrigated lands and from 2.4 to 3.0 t/ha on dry lands, exceeding the standard cultivars Kazakhstan 10 and Kazakhstan rannespelaya by up to 0.5 t/ha. In terms of grain quality traits, these spring soft wheat cultivars met the requirements of GOST as valuable wheat (Table 1). For example, the cultivar Bolashak has the raw gluten content of 30.0%, protein

content (15.7%), grain weight (805 g/l), and an alveograph index of 312 joules. The good grain quality indicators of the cultivar Bolashak acquired validation with the composition of high-molecular-weight glutenin subunits (HMW). The cultivar Bolashak mainly contains the b allele of the Glu-A1 locus, which significantly contributes to improving baking quality. Two alleles controlling WMSG 7+9

Table 2. Economically valuable indicators of promising lines spring soft wheat CVT numbers during 2022–2024.

Catalog	Yield (t/ha)	Sprouting-ear emergence period (days)	Susceptibility to disease (%) / type of reaction			Natural (g/l)	Glass Visibility (%)	Gluten (%)	Protein (%)
			Brown rust	Yellow rust	Stem rust				
Lutescens 528	4.6	62	0	5/R	5/MR	763	58	30.6	13.5
Lutescens 1068	4.6	60	0	0	0	783	57	30.0	13.0
Lutescens 824	4.5	58	0	0	5/R	726	61	32.8	14.7
Lutescens 698	4.9	58	0	0	5/R	762	60	32.4	14.1
Lutescens 702	4.9	57	0	10/MR	5/R	776	59	31.3	13.3
Lutescens 1216	4.8	60	5/R	0	20/MS	781	60	35.3	13.8
Lutescens 739	4.9	58	5/R	5/MR	0	749	63	35.0	14.2
Lutescens 653	4.7	59	5/S	0	10/MR	740	60	38.3	13.3
Lutescens 1148	4.4	62	0	5/R	5/MR	751	64	35.2	14.0
Kazakhstanskaya 10, standard	3.7	62	10/MR	40/S	0	788	62	31.0	13.4
LSD _{0.05}	0.4								

Note: where 0 - immune, R - resistant, MR - moderately resistant, and MS - moderately susceptible.

have been prominent at the Glu-1B locus, as well as the d allele at the Glu-D1 locus, which were the valuable characteristics of high-quality wheat cultivars.

Breeding work on developing new spring wheat cultivars for various regions of Kazakhstan continues today. Currently, the nursery of competitive variety testing (CVT) has identified numerous cultivars with grain yields of around 4.4–4.9 t/ha under irrigation conditions compared with the standard yield of 3.7 t/ha. The promising spring wheat lines showed a statistically significant yield advantage over the standard cultivar Kazakhstanskaya 10, ranging from 0.70 to 1.23 t/ha (LSD_{0.05} = 0.41 t/ha). Among them, the highest yield performance resulted in lines, such as Lutescens 702, Lutescens 1216, Lutescens 698, Lutescens 739, Lutescens 653, Lutescens 1068, and Lutescens 824, with a vegetation period from emergence to heading lasting 57 to 60 days (Table 2). In terms of overall product quality, these cultivars belong to the category of robust and valuable wheat. They showed resistance to rust and were notable as promising genotypes for submission to the State Commission for Variety Testing of Agricultural Crops of the Republic of Kazakhstan (SVT RK) as new cultivars (Table 2).

CONCLUSIONS

Methodological aspects of breeding have succeeded in their identification, ideotypes (non-irrigated, dry-steppe, and intensive types) have reached development, and defining directions of research work have been successful. In addition, 29 spring wheat cultivars and two facultative wheat cultivars (*T. aestivum* L.) have entailed production and release for commercial use. These cultivars are adaptable for cultivation under specific soil and climatic conditions of the RK, the KR, and the RF. They also represent new sources of valuable traits and characteristics for the work of plant breeders and geneticists. Currently, in the Competitive Variety Testing (CVT) nursery, detecting numerous spring bread wheat lines with grain yields under irrigation of about 4.4–4.9 t/ha (compared with the standard yield of 3.7 t/ha) is in progress, along with other positive economically valuable traits and properties. The best of them will subsequently proceed for submission as new cultivars to the SVT RK.

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