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RESEARCH ARTICLE
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Study of Varieties and Lines of Winter Wheat (*Triticum Aestivum*) On Drought Resistance in the South-East of Kazakhstan

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ABSTRACT

In Kazakhstan, winter wheat is grown in the south and south-east of the country on an area of more than 520 thousand hectares. Winter wheat is grown mainly on rain-fed lands, where precipitation amounts to 180-350 mm per year. Due to climate change, wheat's drought resistance is a global problem, and despite some success, the study of individual mechanisms of winter wheat's drought resistance, the identification of genotypes with signs of drought resistance, as well as the study of their disease resistance, yield and grain quality is relevant for the republic. Field and laboratory studies of 14 genotypes of winter soft wheat for drought resistance were carried out. Correlation analysis (the relationship between traits and yield) showed that the weight of grains per plant GWP (r = 0.87) is the main factor in the yield of the winter wheat varieties and lines we studied. The number of spikelets per main spike SNMS (r = 0.75) also had a strong influence to yield. The grain weight per main spike GWMS (r = 0.69) and the weight of 1000 grains TGW (r = 0.64) also showed a high correlation with yield, but were slightly inferior to the grain weight per plant GWP. Plant height PH (r = 0.58) and number of grains per spike GNMS (r = 0.49) showed a moderate correlation with yield. In our studies, main spike length MSL (r = 0.24) did not affect yield. These parameters correlated with relative water content (RWC) in the experimental seedlings. Photosynthetic pigment content correlated with the level of water-soluble proteins under stress. Varieties and lines differed in morphology (botanical variety) did not show the same yield and its components.

Keywords: Wheat, Variety, Yield traits, Drought, Resistance, Physiological parameters.

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INTRODUCTION

Kazakhstan has traditionally been a major producer of high-quality, strong and particularly valuable wheat. In southern and south-eastern Kazakhstan, winter wheat is the main grain crop. The average annual production of winter wheat in recent years has been 1.1-1.2 million tonnes, with an average yield of 2.2-2.4 tonnes per hectare. The territory of Kazakhstan is characterized by a variety of natural and climatic zones and extreme instability of meteorological conditions from year to year and season to season. In recent decades, the number of stress factors affecting the size and quality of the winter wheat harvest has increased dramatically. Various studies have demonstrated the extensive impact of climate change on agricultural productivity, consistently confirming its adverse effects on global food production and predicting even more severe consequences for crop yields in the future (Langridge & Reynolds, 2021; Prăvălie, 2021; Hussain et al., 2021; Saeed et al., 2024). Breeding drought-tolerant and high-yielding crop varieties remains one of the most effective strategies for mitigating drought-related challenges worldwide (Khadka et al., 2020; Langridge & Reynolds, 2021; Reynolds et al., 2021). Plant drought tolerance is a complex trait influenced by the genetic background of varieties and the coordination of physiological and biochemical processes, reflecting a genotype's ability to maintain high yields under water-deficient conditions (Ahmed et al., 2020).

Various strategies for improving wheat's resistance to heat and drought have been studied worldwide,

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including extensive genetic analysis and modification of the expression of genes involved in stress response, targeting specific physiological traits, and direct selection under various stress scenarios. These approaches have been combined with improvements in phenotyping, the development of genetic and genomic resources, and the expansion of screening and analysis methods (Langridge & Reynolds, 2021). To improve the efficiency of drought-tolerant variety selection, it is recommended to select indicators that can accurately indicate the drought tolerance of a variety (Bao et al., 2023). Some authors believe that drought resistance is controlled by polygenes, and their expression is influenced by various environmental factors that cause drought stress (Zafar et al., 2023). The literature describes many physiological and biochemical indicators that correlate with drought resistance, where the most important factors determining resistance are the accumulation of green matter that ensures photosynthetic activity, the level of free proline, and others (Albayrak et al., 2021).

Drought resistance is a complex trait, and many factors must be taken into account: growth, leaf color and pubescence, plant height, internode length, stem position, ears, and grain size. Understanding the complex mechanisms underlying wheat's response to drought is essential for breeding drought-tolerant varieties. (Kumar et al., 2020; Nazarenko et al., 2022, Aidarbekova et al., 2024; Zhang et al., 2024). Wheat has been observed to have varying levels of drought resistance mechanisms, including changes in the physiological processes of plant leaves. Metabolic disorders and significant yield losses are the result of the activation of various mechanisms, including water and mineral uptake, CO_2 assimilation, transpiration, stomatal conductance, chlorophyll concentration, stomatal density, and cell wall integrity (Guizani et al., 2023). The evaluation of hybrid, breeding and collection material under conditions of extremely dry summer conditions has made it possible to identify valuable winter wheat varieties that combine resistance to atmospheric and soil drought (Rsaliev et al., 2024). In the southern and southeastern regions of Kazakhstan, winter bread wheat varieties developed by the Kazakh Research Institute of Agriculture and Plant Growing are extensively cultivated, covering approximately 360,000 hectares across areas with secure, semi-secure, and harsh *bogara* (rainfed conditions), as well as in foothill, mountainous, and irrigated zones. The diversity of agroecological zones and varietal types necessitates tailored cultivation practices that align with the specific characteristics of each variety and the prevailing weather and climatic conditions of the growing season. In the southeastern and southern regions of the country (Almaty, Zhetysu, Zhambyl, and South Kazakhstan), the following winter wheat varieties are officially recommended for dryland farming: *Kyzyl bidai*, *Bogarnaya 56*, *Egemen 20*, *Steklovidnaya 24*, *Dulati*, *Talimi 80*, *Momyshuly*, and *Vavilov*. These belong to the steppe and dry-steppe agroecotypes and are classified as medium-early maturing. They are characterized by high to moderate frost and winter hardiness, strong heat and drought tolerance, moderate resistance to rust diseases, resistance to smut, and non-shattering at maturity while ensuring good threshability. Due to their strong ecological adaptability, these varieties produce high yields under favorable climatic conditions and maintain stable, reliable productivity during dry or unfavorable years. Based on assessments of their technological grain qualities, these cultivars are categorized as strong and valuable wheat types. Our study presents the results of research into 14 genotypes of winter soft wheat, including varieties and promising lines, under field and laboratory conditions, which can be used in crossbreeding and the creation of drought-resistant forms. The aim of the research was to identify drought-resistant varieties of winter bread wheat for rain-fed farming in field and laboratory conditions and to determine their specificity in terms of morphological and physiological adaptability parameters for south-eastern Kazakhstan.

MATERIALS & METHODS

The experiment was conducted on light chestnut rainfed soil located on the foothill-sloping plain of the northern slope of the Ili Alatau (latitude 43°268097′N; longitude 76°683860′ E). The plain has a general slope in the northern direction from the Ili Alatau. The content of total humus in the arable layer fluctuates mainly low within 1.60-1.90% with a content on virgin soil of 2.20-2.40%. The content of total nitrogen is 0.15%, total phosphorus - 0.21%, total potassium - 1.67%. The reaction of the soil solution is slightly alkaline (pH = 7.8). According to the granulometric composition, the studied soils are classified as medium loamy with a physical clay content of 35-43% and physical sand - 57-65%. A total of 14 winter wheat varieties and breeding lines were cultivated under field conditions during 2022–2024 to evaluate their drought tolerance. The analyzed varieties, along with their botanical classifications and origins, are presented in Table 1.

Sowing was carried out on plots measuring 10 m^2, in three replicates. Yield and yield components were determined in accordance with the methodological recommendations "Methods for organizing and conducting a grain yield survey" (MoA, 2018) and "Rules for conducting variety testing of agricultural plants" (Republic of Kazakhstan, 2021). The following indicators were evaluated: plant height (PH), main spike length (MSL), number of spikelets per main spike (SNMS), number of grains per main spike (GNMS), grain weight per main spike (GWMS), grain weight per plant (GWP) and thousand grain weight (TGW). In laboratory analyses, the contents of photosynthetic pigments—chlorophyll *a* (Ca), chlorophyll *b* (Cb), and total chlorophylls (*Cx* + *c*)—were determined in the leaves of the experimental plants, along with carotenoid concentration, relative water content (RWC), and water-soluble protein content (WSPC). The control treatment was included for comparative evaluation.

Table 1: Winter wheat Genotypic Description

№	Variants	Botanical variety	Origin
1	Vavilov	Erythrospermum	Mironovskaya 808/Obriy
2	Kyzyl bidai	Erythrospermum	Yuzhnaya-12/ Albatros Odeskiy
3	Bogarnaya 56	Pyrotrix	Yubileinaya Osetii/Octoploid Triticale LV-1 // Bezostaya-1
4	Egemen 20	Erythrospermum	50431 (Bulgaria)/Bogarnaya-56
5	Steklovidnaya 24	Erythrospermum	G-1781-83P/Rostovchanka
6	Dulati	Barbarossa	MK 3677/Naz
7	Talimi 80	Erythrospermum	Taza/ Mironovskaya ostistaya
8	Momyshuly	Erythrospermum	OPAKS-18/Albatros odesskiy
9	20388-3	Barbarossa	Naz/d 15 KSI bog 07
10	20841-2	Barbarossa	Oktava/Zhalyn
11	19051-11	Barbarossa	Reke/Naz
12	19251-1	Barbarossa	Eritrospermum 8794/Naz
13	20389-1	Erythrospermum	Zhalyn/Naz
14	20002-6	Barbarossa	[(Attila/(Bogarnaya-56/PRINIA//STAR (Mexico)]//Steklovidnaya-24

Drought resistance was evaluated under laboratory conditions using 12-day-old seedlings grown in Petri dishes under two treatments: a control and an stressed conditions. In the control treatment, the root zone was maintained in an aqueous medium, whereas in the experimental treatment, the roots were subjected to osmotic stress. For this purpose, the experimental seedlings were exposed to a 17.6% sucrose solution in the root zone for two days. This sucrose concentration corresponds to an osmotic pressure of approximately 17 atm, which effectively simulates water-deficit conditions (Drozdov & Udovenko, 1988). The relative water content (RWC) in the seedlings of control and experimental wheat plants was determined and calculated in accordance with Barr and Weatherley (1962). Chlorophyll and carotenoids were extracted from leaf cuttings with 80% acetone, the concentration of chlorophyll a and b and carotenoids were determined on a spectrophotometer at wavelengths of 646.8, 663.2 and 470 nm in accordance with formulas by Wellburn (1994). The content of water-soluble proteins in seedlings was determined by the Bradford (1976) method.

Statistical analysis of the experimental data was performed using JASP software (version 0.95) for descriptive and inferential statistics. Multivariate analyses were carried out to explore patterns of trait variability and relationships among genotypes. Principal component analysis (PCA) was conducted using the prcomp() function in R software (version 4.5.1) (R Core Team, 2025) to identify the major components explaining phenotypic variation under drought stress. The results were visualized using biplots generated with the biplot() function to illustrate the distribution of genotypes and the contribution of individual traits to the principal components. All graphical visualizations (e.g., boxplots, correlation matrices, and PCA biplots) were produced in R using the ggplot2 and factoextra packages to ensure clear representation of statistical relationships and grouping patterns among the studied genotypes.

RESULTS

One of the main limiting factors of the weather conditions of the zone affecting the level of wheat productivity is the amount of precipitation and air temperature during the growing season of plants. The meteorological conditions of the studied years differed significantly from the average annual values and were characterized by a wide variety. According to the data presented in Fig. 1, the weather conditions during the study period differed markedly from the long-term climatic averages. The growing season was characterized by a delayed onset of spring, low soil temperatures during the tillering and heading stages, and pronounced fluctuations between daytime and nighttime air temperatures. These adverse and unstable environmental conditions significantly influenced the overall growth and developmental dynamics of the plants.

Under the agro-climatic conditions of the study area, winter wheat resumed tillering after overwintering and continued this phase until mid-April. The stem elongation phase occurred from the second decade of April to the first decade of May, followed by flowering in the latter half of May and grain filling throughout June. During the study period, 2023 was characterized by the lowest precipitation levels, particularly during the flowering and grain-filling stages, which markedly affected the yield of varieties cultivated under non-irrigated (*bogara*) conditions (Fig. 1). In 2023, the varieties Kyzyl Bidai and Egemen 20 exhibited the highest yields, while the breeding lines 20388-3, 20841-2, 19051-11, 19251-1, 20389-1, and 20002-6 showed significantly reduced productivity under drought stress. In contrast, the favorable weather conditions of 2024 resulted in considerably higher yields, with varieties Kyzyl Bidai, Egemen 20, Talimi 80, and Momyshuly achieving grain yields exceeding 3.0 tha^{-1}.

Across the years of field experimentation under rainfed conditions, the grain yield of winter wheat varieties and breeding lines showed considerable variation depending on climatic fluctuations. On average, yields ranged from 1870kg/ha in line 19251-1 to 2950kg/ha in variety Egemen 20 (Fig. 2). These differences clearly reflected the diverse adaptability of the studied genotypes to moisture-limited environments. Throughout the three-year observation period, plant height (PH) varied from 77.78cm in line 19251-11 to 102.23cm in variety Bogarnaya 56, indicating differences in growth vigor and biomass accumulation. The main spike length (MSL) ranged between 8.43cm in 19251-1 and 10.73cm in Momyshuly, while the number of spikelets per main spike (SNMS) extended from 12.18pcs in 19251-1 to 18.83pcs in Egemen 20. Similarly, the number of grains per main spike (GNMS) varied from 34.18 in 19251-1 to 48.05 in 20388-3, showing clear genotypic differentiation in reproductive potential.

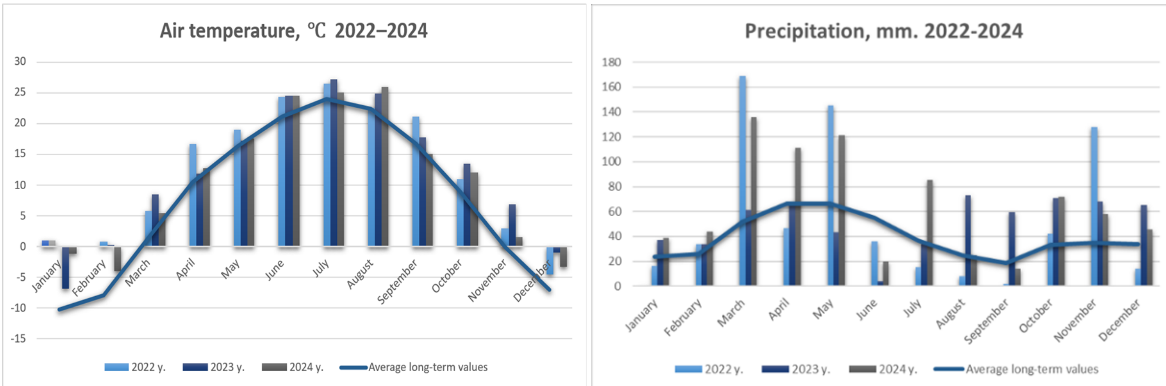

Fig. 1: Changes in air temperature and precipitation in Almaty region (Kazakhstan).

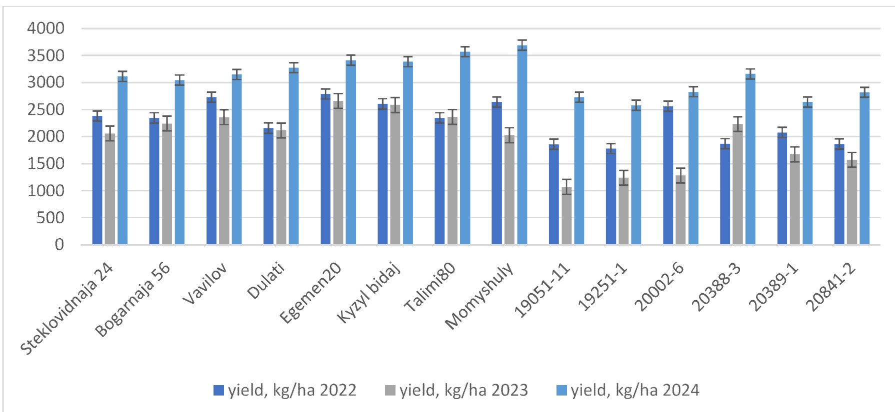

Fig. 2: Yield of winter bread wheat, 2022-2024.

Table 2: Yield and its component of samples studied (average (2022-2024)

Variants	NPT	PH, cm	MSL, cm	SNMS	GNMS	GWMS, g	GWP, g	TGW, g	Yield, kg/ha
Steklovidnaja24	2.77	91.97	10.35	17.13	40.78	1.66	3.82	41.10	2518
Bogarnaja 56	2.87	102.23	9.35	16.57	36.20	1.34	3.32	37.57	2543
Vavilov	3.40	90.40	9.70	17.60	40.90	1.56	4.36	39.07	2747
Dulati	2.53	101.53	9.20	17.30	39.50	1.42	2.92	38.27	2517
Egemen20	3.13	96.33	8.38	18.83	46.02	2.10	5.09	40.40	2954
Kyzyl bidaj	2.65	88.20	10.65	18.37	41.17	1.99	4.28	39.42	2859
Talimi80	2.92	92.07	10.53	18.73	45.87	2.43	5.30	42.37	2760
Momyshuly	2.53	90.37	10.73	17.17	42.17	1.86	4.44	37.42	2785
19051-11	2.50	79.98	9.71	16.13	40.25	1.54	2.92	35.37	1886
19251-1	2.42	77.78	8.43	14.70	34.18	1.28	2.31	34.92	1867
20002-6	2.33	79.53	9.48	16.23	40.05	1.26	2.41	30.34	2224
20388-3	2.93	77.83	9.91	17.13	48.05	1.51	3.85	29.33	2420
20389-1	2.55	87.42	10.58	12.18	40.53	1.43	2.80	32.06	2129
20841-2	2.53	90.43	9.53	16.47	41.37	1.51	2.75	34.01	2085

The thousand-grain weight (TGW) ranged between 29.33g (20388-3) and 41.10g (Steklovidnaya 24) (Table 2). Overall, these findings highlight substantial genotypic variability among the evaluated winter wheat lines. Varieties combining greater spike size, higher grain number, and heavier seeds—such as Egemen 20 and Steklovidnaya 24—demonstrated stronger adaptive potential and higher yield stability under fluctuating rainfall conditions typical of southern Kazakhstan.

According to our research samples, the greatest contribution to yield is made by the weight of grains per plant and spike, as well as the number of spikelets in spike. The varieties Yegemen 20, Kyzyl Bidai, and Momyshuly were the best in terms of the combination of traits. Traits such as spike length and height are not key in themselves, but can indirectly support yield. Correlation analysis (the relationship between traits and yield) showed that the weight of grains per plant GWP ($r = 0.87$) is the main factor in the yield of the winter wheat varieties and lines we studied. The number of spikelets per main spike SNMS ($r = 0.75$) also had a strong influence to yield. The grain weight per main spike GWMS ($r = 0.69$) and the weight of 1000 grains TGW ($r = 0.64$) also showed a high correlation with yield, but were slightly inferior to the grain weight per plant GWP. Plant height PH ($r = 0.58$) and number of grains per spike GNMS ($r = 0.49$) showed a moderate correlation with yield. In our studies, main spike length MSL ($r = 0.24$) did not affect yield (Fig. 3).

Table 3 presents data on the content of photosynthetic pigments in the leaves of experimental wheat seedlings. The highest content of chlorophyll a (*Ca*) was found in cultivars: Steklovidnaya 24, and numbers 19051-11. There are similar trends in the content of chlorophyll b (*Cb*). The samples Momyshuly (Kazakhstan), line 19051-11 (Kazakhstan), were characterized by the highest carotenoids content (*Cx+c*).

The water retention capacity of all samples was quite high (Fig. 4), however, for a number of varieties: Kyzyl Biday, Egemen 20, Dulati, as well as numbers: 19051-11, 19251-1, the decrease in relative water content under stress was less than 1%. Line 20002-6 revealed a significant decrease in water availability.

Table 3: The content of photosynthetic pigments in the leaves of experimental plants

№	Varietys	*Ca,* mg/g	*Cb,* mg/g	*Cx+c* , mg/g
1	Vavilov	0.94	0.33	0.21
2	Kyzyl bidai	1.05	0.37	0.22
3	Bogarnaya 56	1.04	0.37	0.22
4	Egemen 20	1.11	0.37	0.24
5	Steklovidnaya 24	1.32	0.45	0.24
6	Dulati	0.97	0.35	0.21
7	Talimi 80	0.97	0.36	0.22
8	Momyshuly	1.18	0.41	0.26
9	20388-3	1.13	0.39	0.25
10	20841-2	0.98	0.36	0.20
11	19051-11	1.22	0.42	0.26
12	19251-2	0.99	0.36	0.21
13	20389-1	0.97	0.34	0.22
14	20002-6	1.49	0.51	0.33

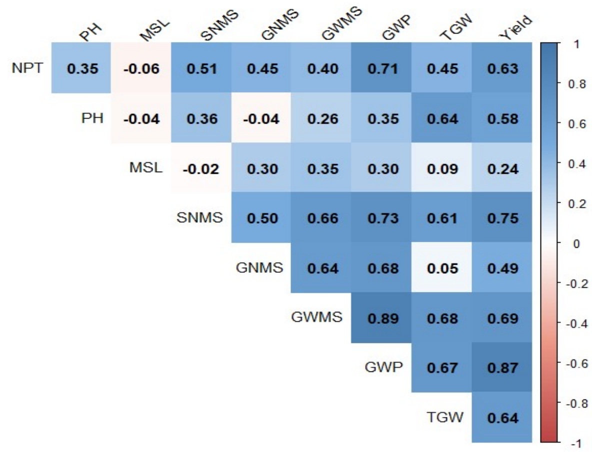

Fig. 3: Correlation coefficients among the yield and its element of 14 winter wheat varieties and lines; NPT –number of productive tillers, PH – plant height, MSL- main spike length, SNMS-spikelet numbers from the main spike, GNMS-grain numbers from the main spike, GWMS – grain weight from the main spike, GWP – grain weight per plant, TGW- thousand grain weight.

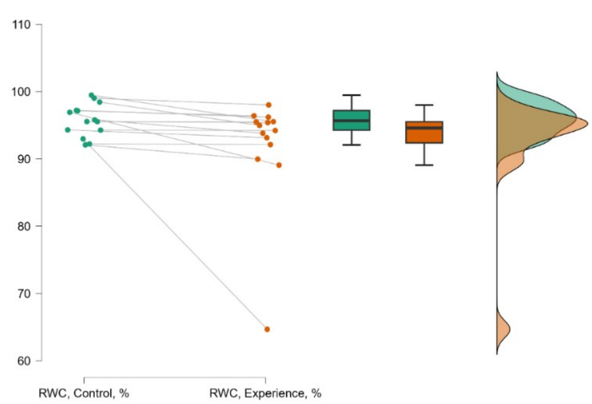

Fig. 4: The relative water content (RWC) in leaves.

Analysis of the content of water-soluble proteins in the leaves of experimental and control plants showed significantly decreasing them in experimental plants (Fig. 5), while at the same time, samples were isolated in which the content of protective proteins remained above 30%. These include the varieties, Steklovidnaya 24, Talimi 80, as well as the numbers 20388-3, 18957-8, 20002-6.

Yield data and biochemical parameters of the varieties were analysed by Principal Components Analysis. The PCA results based on the average values of the studied traits showed that PC1 and PC2 explained 66.2% of the total variation. PC1 explained 44.3% of the total variation, while PC2 explained 21.9% of the total variation. The resulted PCA biplot (Fig. 6) showed that number of productive tillers (NPT) was correlated with number of spikelets in the main spike, seed weight per main spike, and seed weight per plant. These parameters correlated with relative water content (RWC) in the experimental seedlings. Photosynthetic pigment content correlated with the level of water-soluble proteins under stress. As can be seen from Fig. 6 of our research, it can be concluded that the studied varieties and lines are divided into two groups. In the first group, varieties Egemen 20, Kyzyl Bidai, Vavilov Talimi 80, Momyshuly showed results on PH, MSL, SMS, GMS, GMS, GWP, TGW and RWC. The second group was closer to varieties Steklovidnaya 24, 20388-3 and 20002-6 in terms of WSPC. Despite the complexity of the combination of traits for drought tolerance, the studied lines and varieties could be attracted for further use in breeding to develop new varieties of winter soft wheat.

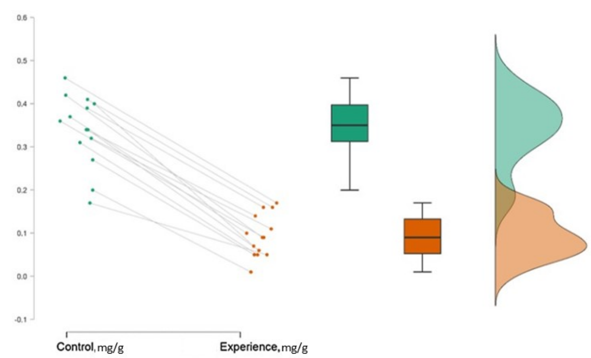

Fig. 5: The content of water-soluble proteins in control and experience variants.

It should be noted that the majority of the lines that are included in the left side of the biplot (20388-3, 20841-2, 19051-11, 19251-2, 20002-6) and the Dulati variety by morphotype belong to the botanical variety *barbarossa*, while the majority of the variety samples grouped by the constant relationships of the yield elements belong to *erythrospermum*. Correlation analysis performed on the data for the group with the erythrospermum varieties (Table 4a) showed that the yield of the variety samples was strongly associated with SNMS (r=+0.93), which in turn affected GWMS (r=0.68), GWP (r=0.86) and TGW (r=0.92). The relationship between the yield and physiological parameters was either negative, as in the case of the concentration of photosynthetic pigments and water-soluble proteins in the seedlings of the stressed conditionss, or weakly positive with RWC (r=0.34). In the samples of winter wheat of the barbarossa variety, plant height had a more pronounced relationship with yield than in the group of plants of the erythrospermum variety (r= 0.53) (Table 4b). The yield of the genotypes of this group also depends on SNMS, however, unlike the genotypes of the erythrospermum variety, there is no relationship with TGW. This group of varietal samples has smaller grains.

The content of photosynthetic pigments negatively correlated with the mass of a thousand grains and plant height. RWC positively correlated with yield elements such as the number of productive stems (NPT), GWMS, and negatively with the content of photosynthetic pigments and water-soluble proteins.

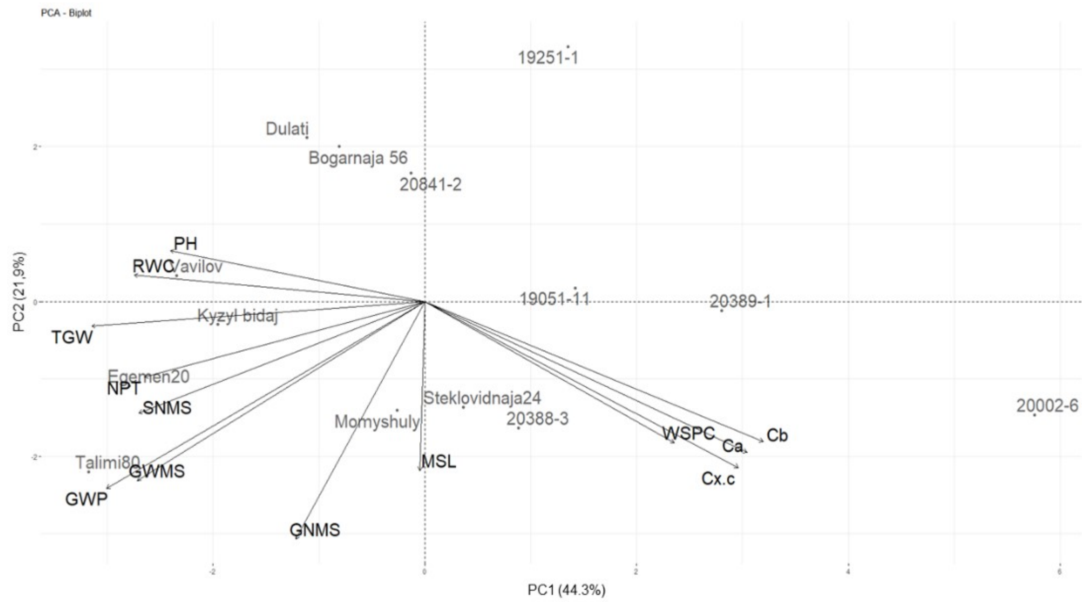

Fig. 6: PCA biplot for yield component traits and physiological parameters; PH – plant height, NPT –number of productive tillers, MSL- main spike length, SNMS-spikelet numbers from the main spike, GNMS-grain numbers from the main spike, GWMS – grain weight from the main spike, GWP – grain weight per plant, TGW- thousand grain weight, RWC- relative water content, WSPC – water soluble proteins, Ca – Chlorophyll a, - Cb- Chlorophyll b, a Cx.c-carotinoids.

Table 4a: Correlation matrix between morphological, physiological, and yield traits of winter wheat varieties and lines of botanical variety a- e*rythrospermum, b- 400barbarossa*

Trait	NPT	PH	MSL	SNMS	GNMS	GWMS	GWP	TGW	Ca	Cb	Cx+c	RWC	WSPC	Yield
NPT	1.00	0.32	-0.67	0.46	0.20	0.07	0.43	0.45	-0.63	-0.63	-0.66	-0.19	-0.13	0.41
PH		1.00	-0.70	0.26	-0.27	-0.17	0.17	0.24	0.25	-0.24	-0.29	-0.65	-0.36	0.15
MSL			1.00	-0.30	-0.11	0.06	0.20	-0.20	-0.45	-0.54	0.24	0.54	0.36	-0.33
SNMS				1.00	0.46	0.68	0.52	0.92	-0.55	-0.55	-0.56	0.11	-0.03	0.93
GNMS					1.00	0.88	0.82	0.48	-0.13	-0.13	-0.11	0.36	0.27	0.52
GWMS						1.00	0.89	0.79	-0.51	-0.51	-0.31	0.21	0.32	0.66
GWP							1.00	1.00	-0.39	-0.35	-0.56	0.29	0.32	0.87
TGW								1.00	-0.39	-0.35	-0.56	0.29	0.32	0.87
Ca									1.00	0.97	0.82	-0.10	0.55	-0.55
Cb										1.00	0.78	0.35	0.45	-0.59
Cx+c											1.00	0.10	0.40	-0.40
RWC												1.00	-0.10	0.34
WSPC													1.00	-0.70
Yield														1.00

Table 4b: Correlation matrix between morphological, physiological, and yield traits of winter wheat varieties and lines under stressed conditions

Trait	NPT	PH	MSL	SNMS	GNMS	GWMS	GWP	TGW	Ca	Cb	Cx+c	RWC	WSPC	Yield
NPT	1.00	-0.08	0.53	0.55	0.83	0.63	0.69	-0.37	-0.26	-0.35	-0.23	0.57	0.33	0.47
PH		1.00	-0.05	0.55	-0.08	0.19	0.62	0.69	-0.50	-0.48	-0.49	-0.26	-0.66	0.53
MSL			1.00	0.72	0.68	0.68	0.70	-0.46	0.03	-0.04	0.04	0.12	0.26	0.36
SNMS				1.00	0.16	0.53	0.69	-0.59	0.00	0.10	0.20	0.13	0.30	0.86
GNMS					1.00	0.62	0.90	-0.34	-0.33	-0.38	-0.35	0.10	0.53	0.57
GWMS						1.00	0.70	1.00	-0.13	-0.21	-0.08	0.53	0.64	0.90
GWP							1.00	-0.34	-0.59	-0.58	-0.61	0.46	0.62	0.55
TGW								1.00	1.00	1.00	0.98	0.90	-0.77	-0.12
Ca									1.00	1.00	0.98	-0.78	-0.83	-0.03
Cb										1.00	0.98	-0.83	-0.77	-0.06
Cx+c											1.00	-0.77	-0.77	0.05
RWC												1.00	1.00	-0.03
WSPC													1.00	0.25
Yield														1.00

Table 5: Yield and physiological parameters of cultivar samples of two botanical varieties

Botanical variety	NPT	PH	MSL	SNMS	GNMS	GWMS	GWP	TGW	Ca	Cb	Cx+c	RWC	WSPC	Yield
E	2.85	92.37	10.03	17.07	41.71	1.80	4.18	38.68	1.11	0.39	0.23	95.47	0.09	26.63
B	2.54	84.51	9.38	16.33	40.57	1.42	2.86	33.71	1.13	0.40	0.24	88.51	0.10	21.68

E - *erythrospermum*, B- *Barbarossa*.

DISCUSSION

Weather anomalies in recent years show that in Kazakhstan special attention should be paid to increasing the resistance of plants to temperature stress. It is important to identify genotypes with signs of drought and heat resistance among local varieties, collectible and breeding material, as well as to study their resistance to diseases, yield and grain quality. The studies evaluated the yield and its elements of the varieties of soft winter wheat approved for use, marked as adapted to the conditions of the South-East of Kazakhstan in the year of their admission. The varieties were created in different years, and climatic changes during this period could affect the appearance of yield signs in conditions of non-irrigated agriculture to varying degrees. For example, the Bogarnaya 56 and Steklovidnaya 24 varieties were created more than 30 years ago, and their yields are inferior to those created at a later date (Vavilov, Egemen 20, Kyzyl biday, Talimi 80, Momyshuly, Table 2). In Fig. 6 (PCA biplot), the Bogarnaya 56 and Steklovidnaya varieties, as well as the Dulati variety and promising lines of competitive variety testing, were outside the group of varieties with the best indicators of yield elements. With the exception of the old-fashioned varieties (Bogarnaya 56 and Steklovidnaya 24) and line 20389-1, all samples belong to the barbarossa variety. Table 5 shows the 3-year average yields and physiological parameters of two groups, differentiated by morphology: E- *erythrospermum*, B- *barbarossa*.

In terms of yield and its elements, cultivars of the botanical variety *erythrospermum* were characterized by higher yields, which averaged 2,663 kg/ha over 3 years. All morphological parameters were also higher in this botanical variety.

Wheat of the botanical variety erythrospermum prevails among the varieties of winter wheat created at our institute. Moskalets et al. (2023) it is also noted that of the more than 721 varieties of common wheat that are registered in the State Register of Plant Varieties of Ukraine, spinous (erythrospermum) and spineless (lutescens) varieties predominate. The author notes that hexaploid variety of common wheat Triticum aestivum L. var. barbarossa (Alef.) Mansf. is known as a source of grain quality traits and it is worth noting that the involvement of biotypes of the barbarossa species in breeding allows obtaining varieties characterised by an average grain yield and winter hardiness, a high content of gluten (36.4 and 37.3%) and protein (15.8 and 18.2%). The similarity of wheat varieties in morphological characteristics also leads to a narrowing of genetic diversity, and therefore it is necessary to involve in the selection sources of new plant organ traits associated with resistance to adverse environmental conditions, with productivity and grain quality. Landraces belongs to different and rare botanical varieties can be used for increasing the biodiversity of newly developed varieties of wheat, be able to resist to unfavorable stresses (FAO, 2015, Babissekova et al., 2025). Approximately 70% of the landraces were mixtures of different species or morphotypes. (Morgounov et al., 2016).

Bao et al. (2023) evaluated 24 drought-related indices, including yield, morphology, photosynthesis, physiology, and osmotic regulation in wheat, under drought stress conditions. Among them plant height (PH), spike number (SN), spikelets per spike (SP), Canopy temperature (CT), leaf water content (LWC), photosynthetic rate (A) and activity of antioxidants were associated with wheat drought resistance. Yield-related and physio-biochemical (chlorophyll contents, relative water content, membrane stability index, leaf nitrogen, phosphorus, and potassium content) traits p*arameters* increased under the stress in all 11 wheat varieties under drought stress but the most indices were determined in genotype with higher biological and grain yield (Ahmad et al., 2022). Among the physiological response of the genotypes to drought stress tolerance RWC and chlorophyll content are using regulary to screening drought-tolerant genotypes of bread wheat (Rijal et al., 2021; Sewore et al., 2023).

Leaf Relative Water Content (LRWC) is a key physiological parameter widely used to evaluate drought tolerance among wheat genotypes (Mohi-Ud-Din et al., 2021; Shah et al., 2022). In the present study, the relative water content of seedlings remained comparatively high under both control and stress conditions. Notably, only one line exhibited a significant decline in LRWC under drought stress. Principal Component Analysis (PCA) indicated that greater water availability, as inferred from LRWC values, was observed under laboratory conditions. Furthermore, the concentration of photosynthetic pigments serves as an important indicator of the plant's capacity to withstand drought, reflecting its physiological adaptability under stress (Qiao et al., 2024). The contents of photosynthetically active pigments (chlorophyll a and b and carotenoids) were influenced by the gene type (Hnilicka et al., 2023).

Our results revealed considerable variability in the levels of photosynthetic pigments among the evaluated wheat genotypes. The highest concentrations of chlorophyll *a* and *b* were recorded in cultivars *Steklovidnaya 24* and line 19051-11. Notably, the pigment content appeared independent of the leaf relative water content (LRWC). Drought stress exerted a pronounced influence on the accumulation of osmolytes in wheat leaves, consistent with previous findings (Yang et al., 2024). Osmolytes are compatible solutes that accumulate rapidly in plants under water deficit, contributing to cellular osmotic balance. Their enhanced accumulation improves plant water status, thereby sustaining photosynthetic activity, minimizing oxidative stress, and ultimately promoting grain yield (Wang et al., 2019). In the present study, wheat plants demonstrated osmotic adjustment through the accumulation of free amino acids, soluble sugars, and soluble proteins, corroborating earlier reports (Qayyum et al., 2021; Ozturk et al., 2021). The content of water-soluble proteins—considered key osmolytes—was assessed in winter wheat seedlings exposed to water deficit. Under control conditions, the concentrations of these compounds were relatively low, whereas a pronounced decline was observed under drought stress, indicating their sensitivity to water limitation. Contradictory results were found in the literature about leaf protein contents in crops under drought conditions. For instance, Rodriguez et al. (2002) reported that sunflower plants subjected to water shortage experienced a decline in leaf soluble proteins, whereas Ashraf and Mehmood (1990) have noted a high drought tolerance in crops which has been correlated with higher amounts of proteins. The concentration of soluble proteins is dependent on the nature of plant species and the type of tissue under water stress (Tahkokorpi et al., 2007).

In our case, a possible explanation for the observed discrepancy in results may be that soluble proteins did not function effectively as osmolytes, or that alternative compounds served as the primary osmotic regulators under drought stress. It is also important to note that methodological differences may have contributed to this variation. For instance, Qayyum et al. (2021) induced osmotic stress using different concentrations of polyethylene glycol (PEG-6000), which simulates drought conditions through osmotic potential manipulation rather than direct water limitation. Such experimental differences in stress induction could account for variations in osmolyte composition and physiological responses observed across studies.

Conclusion

The evaluation of fourteen winter bread wheat varieties and promising lines carried out from 2022 to 2024 under rainfed conditions in the South-East of Kazakhstan clearly reflected how shifting climate patterns influence varietal performance. Older cultivars tended to show reduced adaptability and yield stability, while newer genotypes displayed better resilience and productivity under limited water availability. A strong relationship was observed between yield and the relative water content (RWC) of seedlings, emphasizing the importance of water retention as a physiological indicator of drought tolerance. Moreover, the levels of photosynthetic pigments were closely aligned with water-soluble protein content, suggesting that these biochemical adjustments play a vital role in maintaining photosynthetic efficiency under stress. Together, these findings demonstrate that combining physiological and biochemical markers can significantly enhance breeding efforts aimed at producing high-yielding, climate-resilient wheat suited for dryland farming systems in Kazakhstan and similar environments.

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