IIETA International Information and Engineering Technology Association
Advancing the World of Information and Engineering

International Journal of Design & Nature and Ecodynamics
Vol. 19, No. 1, February, 2024, pp. 81-91
Journal homepage: http://iieta.org/journals/ijdne

Impact of New Varieties on the Yield and Quality of Wheat, Oats, and Sudangrass in North-Eastern Kazakhstan

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https://doi.org/10.18280/ijdne.190110

Received: 20 September 2023
Revised: 22 January 2024
Accepted: 29 January 2024
Available online: 29 February 2024

Keywords:
breeding, agricultural crop varieties, crop production, seed production, food security, yield

ABSTRACT

The paper explores breeding and seed production in Northeastern Kazakhstan, specifically focusing on the introduction of new wheat, oats, and Sudangrass varieties by LLP "Pavlodar Agricultural Experimental Station". The research, conducted across 16 experimental sites in various districts of Akmola, North Kazakhstan, Karaganda, Pavlodar, and Kostanay regions, used standard field and laboratory methods to enhance agricultural yields and bolster food security in the region. The varieties of spring wheat (Anel-16 and Ertis 7), oats (Ertis samaly and Mirny), and Sudangrass (Dostyk 15) were investigated. The yield of crops, the weight of 1000 seeds, the protein and gluten content in wheat and oat grains, and the yield of normalised dry matter in the harvest of Sudangrass are determined. Variance and correlation analysis are used for statistical processing. The influence of weather conditions (average daily air temperature, precipitation amount, and Selyaninov hydrothermal coefficient for the growing season 2017-2019) on crop development and protein content in wheat and oat grains, and the herbage of Sudangrass have been established. The most favourable areas of cultivation of the varieties of agricultural crops are indicated.

1. INTRODUCTION

The development of the agricultural sector and the creation of competitive agricultural production are the main tasks of the country's economic security, outlined by the Strategic Development Plan of the Republic of Kazakhstan until 2025 [1]. Agriculture plays a leading role in the agro-industrial complex of the country. The climatic conditions of Kazakhstan allow growing various crops and developing animal husbandry.

Wheat occupies the main place among the grain crops of the republic [2, 3]. The country annually produces about 12 million tonnes of wheat, of which more than 7 million tonnes are exported. Kazakhstan is rightfully considered one of the largest producers and exporters of grain on the world market. The main areas of soft wheat cultivation are located in the north-eastern part of the country: in North Kazakhstan, Akmola, Kostanay, and Pavlodar regions [4]. Forage crops (oats, Sudangrass) also play a crucial role, as selection for improved quality and yield can ensure further development of the livestock industry in Kazakhstan. According to Fant [5], replacing barley with oats in the diet of dairy cows reduces the release of methane by animals into the environment, which is one of the ways to reduce the impact of human activities on climate change, while milk yields and milk quality remain at the same level.

Breeding and seed production of agricultural crops can solve the problem of shortage and diversity of varieties not only in conventional crop production but also in organic crop production [6-8]. The contribution of breeding and seed production to increasing the yield of grain crops is estimated by a number of researchers at 30-70%, and considering global climate changes, in their opinion, it can only grow [9, 10]. According to Dagnoko et al. [11], the use of high-quality seed material of newly approved varieties of agricultural crops increases their yield by 20-25%, while the higher cost of 1 kg of elite seeds (KZT 14000) compared to 1 kg of commercial grain (KZT 8000) provides high economic efficiency [12]. Thus, the variety exchange and the introduction of new varieties and hybrids of high reproductions lead to an improvement in the country's economy.

In the Republic of Kazakhstan, more and more attention has been paid to breeding and seed production in the last 10 years. According to the National Agrarian Scientific and Educational Centre [13], the country produces only about 20% of high-quality seeds that are used for variety renewal and replacement.

As of 2022, 2613 varieties have been entered into the register in the republic, of which 822 (31.5%) are produced in Kazakhstan, 1733 (66.3%) are foreign, and 58 (2.2%) are varieties of joint, Kazakh-foreign selection. Agro-climatic conditions of Kazakhstan vary greatly not only by regions, but also by districts. According to Eroshenko et al. [14], in unfavourable conditions for growing crops, the role of varieties with broad ecological plasticity, which are able to produce stable yields in different cultivation conditions, is much greater than that of various agrotechnical measures. The most effective are precisely the zoned varieties and hybrids that were bred in a particular region [15].

Several factors influenced the selection of these varieties for the study (spring wheat (Anel-16 and Ertis 7), oats (Ertis samaly and Mirny), and Sudangrass (Dostyk 15)):

- Each variety exhibits resistance to significant diseases and demonstrates drought tolerance, rendering it viable for cultivation in arid regions.
- Each variety is of exceptional quality and possesses the capacity to enhance agricultural productivity and promote sustainability in the north-eastern region of Kazakhstan.

More research is needed on the performance of the new varieties (Anel-16 wheat, Ertis samaly oats, and Dostyk 15 Sudangrass) across a wider range of environments and growing conditions in Kazakhstan. The scope of the present investigation was restricted to sixteen sites spanning five regions. Increasing the number of locations where these varieties are tested could aid in the delineation of their adaptation zones. The yield stability and resistance of the new varieties to variable weather conditions, particularly heat and drought stress, could be the subject of additional research. While correlations with temperature and precipitation were examined in the present study, managed stress conditions were not imposed. Further investigation is warranted regarding the most effective agronomic techniques (e.g., fertiliser rates, planting dates) that can be customised for these novel varieties to optimise their yield potential. An additional method for determining the disease resistance of varieties is to subject them to controlled inoculation trials and screening against various pathogen strains.

The lack of evaluation regarding the performance of the varieties in crop rotations, intercropping systems, and mixed forage stands indicates a need for further investigation in this area. Additional research could broaden the scope of the quality assessment of the varieties to include processing qualities, micronutrients, and antioxidants, among others. It is necessary to conduct economic analyses to illustrate the potential financial benefits that farmers could obtain by implementing these novel, higher-yielding varieties. In brief, although this article offers a foundational evaluation of the novel wheat, oats, and Sudangrass cultivars, further investigation is required in various fields (including economics, quality, and agronomy) to provide direction for their prosperous implementation and upkeep in Kazakhstan.

To address this research gap, the present study examines the performance of three Kazakh-bred varieties—Dostyk 15 Sudangrass, Anel-16 wheat, and Ertis samaly oats—in five distinct regions of northeastern Kazakhstan. A variety of factors, including yield, quality, disease resistance, and drought tolerance, will be the focus of the study. The findings of this research will provide farmers and seed producers in north-eastern Kazakhstan with valuable information that will assist them in selecting varieties that are most suitable for their particular environmental conditions. Additionally, researchers will benefit from the study because it will contribute to a more holistic comprehension of the efficacy of Kazakh-bred varieties across various geographical areas.

The purpose of the study was to investigate new varieties of grain and forage crops of Kazakh selection in north-eastern Kazakhstan. The main objects of the study were the original varieties of LLP “Pavlodar Agricultural Experimental Station”: spring soft wheat Anel-16, spring oats Ertis samaly, and Sudangrass Dostyk 15. The objectives of the study included:

1. Analysis of agro-climatic conditions and their impact on new zoned varieties in five regions of north-eastern Kazakhstan.
2. Study of useful varietal characteristics of the crops under study and the prospects of introducing such varieties into production.

2. MATERIALS AND METHODS

The creation and cultivation of zoned varieties of agricultural plants allows increasing their yield in specific agro-climatic conditions, therefore, the analysis of the main meteorological indicators is a mandatory element of this study. The varieties of grain and forage crops under study were grown at 16 variety testing sites in five regions of the republic: Kostanay, North Kazakhstan, Akmola, Karaganda, and Pavlodar, located in steppe, forest-steppe, and mountainous zones. To analyse weather conditions in the years of research (2017-2019), data from 16 weather stations included in the Kazhydromet system of the Ministry of Ecology, Geology, and Natural Resources of the Republic of Kazakhstan were used.

The main factors influencing the growth, yield and quality of crops are air temperature, precipitation, and the indicator of the temperature and moisture regime of the growing season (May-August) – the Selyaninov hydrothermal coefficient (HTC). The latter shows whether the soil moisture conditions were optimal or extreme for plants. The fundamental relationship between the total moisture gained through precipitation and the total moisture likely lost through plant evapotranspiration during the designated growing period is represented by the HTC formula. This provides a moisture sufficiency index for the analysed region and time period. Thus, a value of HTC from 0 to 0.5 indicates a severe drought; from 0.6 to 0.7 – arid regime; from 0.8 to 1 – insufficient moisture; from 1 to 1.5 – sufficient soil moisture; above 1.5 – excess moisture, which also negatively affects the condition of crops and the quality of the future harvest [16]. The HTC was calculated using the equation:

$$\mathrm{HTC} = R / 0.1 * \Sigma t \quad (1)$$

where, R – total precipitation for a certain period (mm); Σt - cumulative temperature for the same period (°C).

Varieties of agricultural crops of the selection of LLP “Pavlodar Agricultural Experimental Station” were investigated:

- Spring soft wheat of the Anel-16 variety, derived by individual selection from hybrid combinations of varieties Irtyshanka 10 × Pavlodar 93;
- Spring oats of the Ertis samaly variety, obtained by hybridisation of parent forms - (Eagle × Taiga) × Selma

and the subsequent complete stabilisation of the genotype;

- Sudangrass of the Dostyk 15 variety, created by individual selection from hybrid combinations Kinelskoye 3 × Brodskaya 2.

Field experiments were conducted according to the generally accepted methodology [17]. The area of each experimental plot under the wheat varieties Anel-16 and Ertis 7 (standard), oats - Ertis samaly and Mirny (standard) was 2 ha, and under the Sudangrass of the Dostyk 15 variety - 1 ha. The repetition was twofold. The names of the institutions where the experiments were conducted are given in Table 1.

Table 1. Place of research of new varieties of grain and forage crops, Republic of Kazakhstan, 2017-2019

Region	Akmola Region	Pavlodar Region	North Kazakhstan Region	Karaganda Region	Kostanay Region
Location	Kokshetau complex STP Sandyktau STP Egindikol STP Zhaksy STP Shortandy STP Tselinograd STP	Pavlodar grain STP Irtysh STP Urlyutyub STS	Esil STP Kazanka STP Ruzaevka STP Arykbalyk STP	Osakarov STP Karkaraly STP	Kazakhstan STS

Note: STP - state variety testing plot; STS - state variety testing station.
Source: Compiled by the authors.

The study of the beneficial characteristics of spring wheat (Anel-16 and Ertis 7) was carried out in three regions (North Kazakhstan, Akmola, and Pavlodar), oats (Ertis samaly and Mirny) - in two (Pavlodar and Karaganda), Sudangrass (Dostyk 15) - in four (Kostanay, Akmola, Karaganda, and Pavlodar).

Laboratory experiments included the determination of such qualitative indicators: the weight of 1000 seeds, the content of gluten and protein, and the weight of dry matter (for Sudangrass). To determine the weight of 1000 grains, two batches of 500 grains were taken, which were weighed with an accuracy of 0.01 g. The gluten content was determined in accordance with GOST RK (ST RK 2234-2012), and protein - GOST 10846-91 [18, 19]. The dry weight of Sudangrass was determined from a trial sheaf (0.5 kg) from which two samples (50 g each) were taken. After complete drying of the fraction, the fraction of dry matter was calculated, and then recalculated per ha.

GOST RK (ST RK 2234-2012) "Grain. Methods for determining the quantity and quality of gluten in wheat" is the national standard of Kazakhstan that specifies procedures for quantifying wet and dry gluten percentage in wheat and rye [18]:

- Gluten is washed out from a meal/flour sample with salt solution.
- The gluten is collected, excess moisture removed, and then weighed.
- Gluten content is calculated as percentage of the original sample mass.
- Standard provides details on specific equipment, reagents, and calculations.

GOST 10846-91 "Grain and products of its processing method for determination of protein" is the interstate standard (Kazakhstan and other countries of Commonwealth of Independent States) outlining the protocol for nitrogen analysis using the Kjeldahl method and conversion to crude protein percentage [19]:

- Samples are digested with sulfuric acid to liberate= organic nitrogen.
- Ammonia from the digestion is distilled and titrated= to quantify nitrogen.
- Nitrogen value is multiplied by 5.7 for wheat or 5.8= for other grains to estimate protein percentage.

Statistical data processing is represented by variance and correlation analysis, the main indicator of the first is the indicator of the reliability of the difference in the results obtained - $LSD_{0.5}$, and the second is the correlation coefficient (r). At the 0.05 level of probability, the LSD values reported in the paper represent the "least significant difference" between treatment means. This methodology offers a statistical assessment of whether the disparities in crop yield data observed among regions and varieties are substantially larger than what would be predicted by random variation in isolation.

When the correlation coefficient is from 0 to 0.19, the influence of the studied factor is absent; at 0.2-0.39 - it is insignificant; at 0.4-0.69 - it is average; at 0.7-1 - it is strong. This coefficient can have a positive or negative value, which indicates the influence of the factor (direct or reverse) [20]. Statistical data processing was carried out on a personal computer using the Statistical software suite.

3. RESULTS

Stationary experimental plots for the study of the main varietal characteristics of grain and forage crops were established on 14 state variety testing plots (STP) and 2 state variety testing stations (STS), located in five regions in north-eastern Kazakhstan. The studies were conducted in 2017-2019, of which 2018 was the wetter year: during the growing season, precipitation ranged from 123 to 302 mm, and the HTC - from 0.6 to 1.7 (Table 2).

During the research period, 2017 was the driest: 2.3-190 mm of precipitation fell during the season, and the hydrothermal coefficient was 0-0.9. In 2019, precipitation amounted to 80-222 mm for the period May-August, and the HTC - 0.4-1. During the years of the study, the most favourable weather conditions for wheat cultivation were in North Kazakhstan, and for oats - in the Pavlodar region. Correlation analysis of the data obtained showed that the quantity and quality of the yield of the crops under study were influenced by weather conditions (Tables 3 and 4).

Thus, heat and moisture had a direct, medium (temperature) and weak (precipitation and HTC) effect on the yield of Anel-16 wheat, and it had a direct but insignificant effect on the protein content. As for the influence of meteorological factors on the yield of oats of the variety under study, it was found that the average daily air temperature had the opposite, average effect, it contributed to the cultivation of oats and the development of a crop at lower temperatures (around 20-23℃), and the amount of precipitation and HTC directly affected the productivity of the crop and had an average impact.

Table 2. Main meteorological indicators during the study period, North-Eastern Kazakhstan, 2017-2019

Site Location	Average Daily Air Temperature for May-August, ℃			Precipitation for May-August, mm			HTC		
	2017	2018	2019	2017	2018	2019	2017	2018	2019
Kostanay Region									
Kazakhstan STS	17.3	16.8	18.1	79	152	222	0.3	0.8	1
North Kazakhstan Region									
Esil STP	17.3	15.5	16.8	43.6	273	150	0.2	1.5	0.7
Kazanka STP	16.8	15	16	13.1	302	171	0.1	1.7	0.8
Ruzaevka STP	17.5	16.1	17.3	190	236	138.1	0.9	1.2	0.6
Arykbalyk STP	17.3	15.8	17	180	198	127	0.9	1	0.6
Akmola Region									
Kokshetau complex STP	17.9	15.9	17.3	147.2	279	108	0.7	1.4	0.5
Sandyktau STP	16.4	14.6	15.7	147.5	236	154	0.7	1.4	0.8
Egindikol STP	19.4	16.9	18.1	12.4	168	166	0	0.8	0.7
Zhaksy STP	18	16.3	17.3	3.1	132	119.8	0	0.7	0.5
Shortandy STP	17.8	15.4	16.6	103.8	244	118	0.5	1.3	0.6
Tselinograd STP	18.6	15.8	17.4	2.3	214	80	0	1.1	0.4
Pavlodar Region									
Pavlodar grain STP	19	16.9	18.2	60	183	158.9	0.2	1.1	0.7
Irtysh STP	19	16.5	17.9	113	153	115.3	0.5	0.9	0.5
Urlyutyub STS	18.8	16.5	17.4	29	178	142	0.1	0.9	0.7
Karaganda Region									
Osakarov STP	18.4	15.7	17.2	25	222	114.2	0.1	1.2	0.6
Karkaraly STP	18.6	16.5	18	102	123	81.6	0.5	0.6	0.4

Source: Compiled by the authors.

Table 3. Influence of weather conditions during the growing season (May-August) on the yield of grain and forage crops of the selection of LLP “Pavlodar Agricultural Experimental Station”, North-Eastern Kazakhstan, 2017-2019

Crop, Variety	Correlation Coefficient (r)		
	Average Daily Air Temperature, ℃	Precipitation Amount, mm	HTC
Spring soft wheat ‘Anel-16’	0.48	0.3	0.25
Spring oats ‘Ertis samaly’	-0.49	0.49	0.51
Sudangrass ‘Dostyk 15’	-0.6	0.22	0.3

Source: Compiled by the authors.

Table 4. Influence of weather conditions on the protein content of grain and forage crops, North-Eastern Kazakhstan, 2017-2019

Crop, Variety	Correlation Coefficient (r)		
	Average Daily Air Temperature, ℃	Precipitation Amount, mm	HTC
Spring soft wheat ‘Anel-16’	0.35	0.31	0.26
Spring oats ‘Ertis samaly’	-0.32	0.43	0.41
Sudangrass ‘Dostyk 15’	-0.6	0.53	0.56

Source: Compiled by the authors.

The average daily air temperature had the opposite, insignificant effect on the protein content of oats of the Ertis samaly variety, and the amount of precipitation during the growing season of the crop and the HTC had a direct, average effect. The average daily air temperature had an inverse, average effect on the growth and development of the herbage of the Sudangrass of the Dostyk 15 variety, and the total precipitation and HTC had a direct, average effect. The temperature regime had an average, inverse effect on the protein content in the herbage of the Sudangrass, and the amount of precipitation per season and HTC had an average, direct effect. Thus, Sudangrass has shown good productivity in hot and arid conditions, which are typical for the north-eastern regions of the Republic of Kazakhstan. Among the varieties of wheat in the Republic of Kazakhstan, the largest areas are occupied by soft spring wheat.

The study analysed quantitative and qualitative characteristics of the usefulness of the mid-late Anel-16 variety in the conditions of north-eastern Kazakhstan. During the years of research, the average yield of this variety on fallow predecessor differed greatly by region and ranged from 13.9 to 41.3 dt/ha, which exceeded the yield of the standard (12.9-38.9 dt/ha) by 0.2-3.7 dt/ha (Table 5).

Table 5. Average yield (dt/ha) of Anel-16 wheat on fallow predecessor, 2017-2019

Site Location	Anel-16				Ertis 7 (Standard)				Deviation from Standard			
	2017	2018	2019	Average	2017	2018	2019	Average	2017	2018	2019	Average
Akmola Region												
Kokshetau complex STP	26.5	32.4	28.8	29.2	25.3	30.1	27.5	27.6	1.2	2.3	1.3	1.6
Sandyktau STP	36.1	29.2	30.9	32.1	33.5	26.9	28.2	29.5	2.6	2.3	2.7	2.5
Egindikol STP	22.2	18.4	19	19.9	21.6	17.4	18.2	19.1	0.6	1	0.8	0.8
Zhaksy STP	18.2	18.6	18.5	18.4	17.2	17.9	17.7	17.6	1	0.7	0.8	0.8
Shortandy STP	22.6	23	24.1	23.2	20.8	20.1	22.6	21.2	1.8	2.9	1.5	2.1
Tselinograd STP	17.6	18.9	17.4	18	16.7	17.1	17.2	17	0.9	1.8	0.2	1
Average by region	23.9	23.4	23.1	23.5	22.5	21.6	21.9	22	1.4	1.8	1.2	1.5
Pavlodar Region												
Pavlodar grain STP	14.1	13.9	14.2	14.1	13.5	12.9	13.1	13.2	0.6	1	1.1	0.9
Irtysh STP	13.9	14.3	14.4	14.2	13.1	13.8	13.6	13.5	0.8	0.5	0.8	0.7
Urlyutyub STS	22	16.6	14.7	17.8	18.3	15.8	13.8	16	3.7	0.8	0.9	1.8
Average by region	16.7	14.9	14.4	15.3	15	14.2	13.5	14.2	1.7	0.8	0.9	1.1
North Kazakhstan Region												
Esil STP	41.3	28.5	29.2	33	38.9	27.4	27.8	31.4	2.4	1.1	1.4	1.6
Kazanka STP	24.6	24.4	24.2	24.4	22.6	22.5	23	22.7	2	1.9	1.2	1.7
Ruzaevka STP	25.3	22.6	24.3	24.1	24.2	21.3	22.9	22.8	1.1	1.3	1.4	1.3
Arykbalyk STP	26.5	23.8	24.4	24.9	24.7	22.9	21.3	23	1.8	0.9	3.1	1.9
Average by region	29.4	24.8	25.5	26.6	27.6	23.5	23.8	25	1.8	1.3	1.8	1.6

Source: Compiled by the authors.

The highest yield of Anel-16 wheat was recorded in 2017 at the Esil STP (North Kazakhstan Region) -41.3 dt/ha, which was 2.4 dt/ha higher than the Ertis 7 variety (standard), as well as at the Sandyktau STP (Akmola Region) -36.1 dt/ha (deviation from the standard +2.6 dt/ha). On the wheat predecessor, the yield of the Anel-16 variety over the years of the study also varied greatly by regions and districts of Kazakhstan and was lower than on fallow. The minimum value was 10.6 dt/ha, and the maximum value -21.3 dt/ha (Table 6). Under the same conditions, the standard showed 8.8-20.2 dt/ha, the deviation from the standard was +0.2-3.1 dt/ha.

Table 6. Average yield (dt/ha) of Anel-16 wheat on wheat predecessor, 2017-2019

Site Location	Anel-16				Ertis 7 (Standard)				Deviation from Standard			
	2017	2018	2019	Average	2017	2018	2019	Average	2017	2018	2019	Average
Akmola Region												
Kokshetau complex STP	15.2	15.8	13.9	15	13.8	14	13.2	13.7	1.4	1.8	0.7	1.3
Sandyktau STP	16.9	15.4	15.8	16	15.4	14.9	15.6	15.3	1.5	0.5	0.2	0.7
Egindikol STP	15.1	14.6	15.1	14.9	13.3	12.8	12.9	13	1.8	1.8	2.2	1.9
Zhaksy STP	14.5	14.6	14.8	14.6	12.5	11.9	12.3	12.2	2	2.7	2.5	2.4
Shortandy STP	15.6	15.8	14.9	15.4	14.1	13.8	14.6	14.2	1.5	2	0.3	1.3
Tselinograd STP	14.1	14.3	15.1	14.5	12.3	13.2	12.7	12.7	1.8	1.1	2.4	1.8
Average by region	15.2	15.1	14.9	15.1	13.6	13.4	13.6	13.5	1.7	1.7	1.4	1.6
Pavlodar Region												
Pavlodar grain STP	11.2	10.9	11.1	11.1	9.7	9.5	9.4	9.5	1.5	1.4	1.7	1.5
Irtysh STP	10.6	11.3	11.2	11	9.9	9.7	8.9	9.5	0.7	1.6	2.3	1.5
Urlyutyub STS	11.9	11.5	11.5	11.6	8.8	9.8	9.2	9.3	3.1	1.7	2.3	2.4
Average by region	11.2	11.2	11.3	11.2	9.5	9.7	9.2	9.4	1.8	1.6	2.1	1.8
North Kazakhstan Region												
Esil STP	21.3	18.5	18.7	19.5	20.2	16.9	17.6	18.2	1.1	1.6	1.1	1.3
Kazanka STP	16.8	15.9	17.1	16.6	15.1	15.3	15.5	15.3	1.7	0.6	1.6	1.3
Ruzaevka STP	19.6	18.6	18.4	18.9	18.3	17.6	16.5	17.5	1.3	1	1.9	1.4
Arykbalyk STP	18.5	18.4	19.1	18.7	16.7	16.6	17.4	16.9	1.8	1.8	1.7	1.8
Average by region	19.1	17.9	18.3	18.4	17.6	16.6	16.8	17	1.5	1.3	1.6	1.4

Source: Compiled by the authors.

Table 7. Qualitative composition of spring wheat grain of Anel-16 variety, 2017-2019

Indicator	Minimum Value	Maximum Value
Weight of 1000 seeds, g	36.1	37.9
Protein content, %	11.8	13.3
Raw gluten content, %	28	33.6

Source: Compiled by the authors.

Table 8. Average yield (dt/ha) of oats of the Ertis samaly variety on wheat predecessor, 2017-2019

Site Location	Ertis Samaly				Mirny (Standard)				Deviation from Standard			
	2017	2018	2019	Average	2017	2018	2019	Average	2017	2018	2019	Average
Pavlodar Region												
Pavlodar grain STP	14.6	15.2	15.5	15.1	13.2	13.6	13.1	13.3	1.4	1.6	2.4	1.8
Irtysh STP	15.8	15.6	15.2	15.5	13.4	14	13.3	13.6	2.4	1.6	1.9	2
Urlyutyub STS	16.1	21.3	17.4	18.3	14.1	15.6	15	14.9	2	5.7	2.4	3.4
Average by region	15.5	17.4	16	16.3	13.6	14.4	13.8	13.9	1.9	3	2.2	2.4
Karaganda Region												
Osakarov STP	15.2	21.4	15	17.2	12.5	16.8	12.9	14.1	2.7	4.6	2.1	3.1
Karkaraly STP	12.3	13.2	12.4	12.6	11	11.4	11.2	11.2	1.3	1.8	1.2	1.4
Average by region	13.8	17.3	13.7	14.9	11.8	14.1	12.1	12.6	2	3.2	1.7	2.3

Source: Compiled by the authors.

The most suitable conditions for the cultivation of spring soft wheat were noted in the conditions of the North Kazakhstan Region (yield on fallow predecessor -22.6-41.3 dt/ha, on wheat predecessor -15.9-21.3 dt/ha), the second place was taken by the Akmola Region (yield on fallow predecessor -17.4-36.1 dt/ha, on wheat predecessor - 13.9-16.9 dt/ha). In the Pavlodar Region, over the years of the study, the yield was 13.9-22 dt/ha (on fallow predecessor) and 10.6-11.9 dt/ha (on wheat predecessor). The analysis of variance showed a significant difference in yield in different areas ($LSD_{0.5}$=2.6). According to qualitative indicators, the following results were obtained (Table 7).

The Anel-16 variety in 2020 was registered in the State Register of Breeding Achievements recommended for use in the Republic of Kazakhstan (Certificate No. 929), recommended for cultivation in North Kazakhstan, Akmola, and Pavlodar regions. Oats and Sudangrass occupy an important place among forage crops. Obtaining new varieties and improving the seed material of these crops, in accordance with the Strategy "Kazakhstan-2050", will stimulate the development of the livestock industry. Experimental plots for the study of spring oats of the Ertis samaly variety were laid in the Pavlodar and Karaganda regions. During the years of the study, yield indicators ranged from 12.3 to 21.4 dt/ha (Table 8), and for Mirny variety (standard) - 11-16.8 dt/ha, that is, the deviation was +1.2-5.7 dt/ha.

The highest yield of the oat variety was observed in 2018 at two experimental sites - Urlyutyub STS (Pavlodar Region) and Osakarov STP (Karaganda Region). The obtained yield indicators did not differ statistically ($LSD_{0.5}$=0.04) and amounted to 21.3 and 21.4 dt/ha, respectively. This small LSD value indicates there were no statistically significant differences (at α = 0.05 level) in average yields of the Ertis samaly oats variety across the different testing sites. The deviation from the standard (Mirny variety) was +5.7 and +4.6 dt/ha, respectively. The main quality indicators of oats of the Ertis samaly variety are shown in Table 9.

The spring oats variety under study was entered into the State Register of Varieties in 2020 (Certificate No. 926) and is recommended for cultivation in Pavlodar and Karaganda regions. Sudangrass is a universal crop from which hay, grass flour, and silage are obtained, and its herbage is also used as a dressing and for grazing livestock. Despite the small area, this crop is very promising. The yield of the herbage of the Dostyk 15 grass in the years of the study varied greatly by region: the highest indicators were noted in the Pavlodar Region (on average - 165.8 dt/ha) (Table 10).

Table 9. Qualitative indicators of spring oat grain of the Ertis samaly variety, 2017-2019

Indicator	Minimum Value	Maximum Value
Weight of 1000 seeds, g	34.9	36.5
Protein content, %	10.1	11.7
Hull content, %	24	28

Source: Compiled by the authors.

Table 10. Average yield of Sudangrass of the Dostyk 15 variety on winter wheat predecessor, 2017-2019

Site Location	Yield of Herbage, dt/ha				Yield of Normalised Dry Matter, dt/ha			
	2017	2018	2019	Average	2017	2018	2019	Average
Akmola Region								
Kokshetau complex STP	75.6	70.6	71.2	72.5	38.2	38.8	37.9	38.3
Sandyktau STP	82.3	80.6	79.9	80.9	40.2	40.7	39.8	40.2
Average by region	78.95	75.6	75.55	76.7	39.2	39.8	38.9	39.3
Pavlodar Region								
Pavlodar grain STP	170.4	166.4	160.6	165.8	47.8	39.5	45.1	44.1
Karaganda Region								
Osakarov STP	97.9	91.2	90	93	39.2	34.3	35.1	36.2
Kostanay Region								
Kazakhstan STS	134	77.3	80.1	97.1	51.1	36.8	31.5	39.8

Source: Compiled by the authors.

In Kostanay and Karaganda regions, the average yield of Sudangrass of the Dostyk 15 variety did not differ significantly ($LSD_{0.5}$=3.8) and amounted to 97.1 and 93 dt/ha, respectively. This larger LSD value suggests there were significant regional differences (at 95% confidence level) in the average dry matter yields obtained from the Dostyk 15 Sudangrass variety. The variance analysis of the normalised dry matter yield showed an insignificant difference by year and region ($LSD_{0.5}$=19.7). In laboratory conditions, it was found that the amount of protein in the herbage of Sudangrass of the experimental variety averaged 15.5%, and fibre averaged 29%. The Dostyk 15 variety of Sudangrass was included in the register of varieties of the Republic of Kazakhstan in 2018, and a patent for the breeding achievement was obtained (No. 917, bulletin No. 45 dated 08.11.2019). This variety is recommended for cultivation in Pavlodar, Akmola, Kostanay, and Karaganda regions. Thus, the results of the study of new varieties of grain and forage crops created at the LLP "Pavlodar Agricultural Experimental Station" showed the productivity and prospects of breeding and seed production work in north-eastern Kazakhstan.

In conclusion, the LSD numbers provide a statistical gauge of whether observed yield differences across sites and years represent true variation or only random noise. Low LSDs suggest consistency, while high LSDs imply meaningful location-based factors influence yields.

However, it should be noted that this study did not specifically control or account for certain additional factors that may have had an impact on the yield and quality parameters of the wheat, oats, and Sudangrass varieties examined. These factors include soil conditions, field microclimates, crop management, and genetic purity.

4. DISCUSSION

Varieties are the basis for the efficient production of plant agricultural products. Modern crop production in conditions of fierce competition and global climatic changes requires high yield returns from crop varieties in various agro-climatic zones, resistance to extreme weather conditions, the possibility of application in modern energy-saving technologies, and high-quality indicators of the harvested crop and resistance to major diseases and pests [21-25]. Breeding and seed production, working with plant material of local origin, can, to some extent, meet the above requirements. The stability of the variety depends on the genomes of the parent forms, and the adaptive reactions of plants allow obtaining high yields [26-28]. However, according to Kazakh researchers, Kurishbaev et al. [29], in recent decades, the introduction of new varieties of grain crops into agricultural production in central and northern Kazakhstan practically does not give an increase in yield indicators, which the authors attribute to the low level of breeding work in the country. The analysis of the breeding and seed production work carried out in the research region, using the example of LLP "Pavlodar Agricultural Experimental Station", indicates a good potential of the new varieties of grain and forage crops.

The results of the conducted studies have shown that the agro-climatic conditions in north-eastern Kazakhstan allow cultivating high-yielding varieties of grain crops with a high protein content. For example, the average yield of spring soft wheat of the Anel-16 variety in 2017-2019 in the Akmola Region was 23.5 dt/ha, and in North Kazakhstan - 26.6 dt/ha; the average protein content - 11.8-13.3%. However, according to the Bureau of National Statistics of the Republic of Kazakhstan, the average wheat yield was 20.1 dt/ha, which indicates the potential of the variety under study. Good indicators of yield and quality were also noted in spring oats variety of the Pavlodar selection - Ertis samaly - 12.3-21.4 dt/ha, protein content in grain - 10.1-11.7%; and Sudangrass of the Dostyk 15 variety - 70.6-170.4 dt/ha of herbage, 31.5-51.5 dt/ha of normalised dry matter, the protein content of the herbage - 15.5%.

According to Serbian researchers, differences in the genotypes of plant varieties of different origin and the period of their vegetation affect the beginning of certain phases of development, therefore, some varieties are less susceptible to the influence of weather conditions, since their phenophase, unlike other varieties, does not fall under the strong influence of extreme climatic factors in the cultivation region [30-32]. Similar results were obtained in the course of this study. Thus, spring wheat of the medium-late maturation type Anel-16 had deviations (3-6 days) in the passage of phenological phases compared to the standard - Ertis 7, and in the years of research Anel-16 grain yield was higher.

A number of researchers claim that the yield of wheat grain is very variable and highly sensitive to the influence of environmental factors [33, 34]. Thus, moisture deficiency is the main limiting factor in increasing the yield of spring wheat and other agricultural crops, therefore, yield variability is high and can reach 30% or more [35-37]. Another reason for low yields is plant damage by diseases of fungal and viral aetiology [38, 39]. Thus, brown rust and Septoria are the most common diseases of grain crops in the region under study. With the combined manifestation of these diseases, grain yield losses can reach 30-40%. Notably, the varieties of spring wheat and oats considered in this paper have resistance to major diseases. The Anel-16 wheat variety has high stability (5 points) and the Ertis samaly oats variety showed average stability (3.8 points).

According to Baisholanov et al. [40] the growth and development of grain crops are strongly influenced by precipitation and air temperatures during the growing season (May-August). Therefore, the most intensive growth of spring wheat is observed in the "tubing-earing" phase, at this time plants consume 50-60% of the total moisture [41, 42]. The researchers showed a direct dependence of the yield of spring wheat on the amount of precipitation for May-August, it was found that with an increase in precipitation and the Selyaninov HTC, the yield also increased. In the course of this study, it was found that the average daily air temperatures had a direct, average effect on the yield of spring soft wheat of the Anel-16 variety ($r=0.48$), and the amount of precipitation and HTC during the growing season of the crop had a direct but insignificant effect ($r=0.3$ and 0.25).

Shaimerdenova [43] analysed the influence of precursors and weather conditions during the growing season on the indicators of the protein-proteinase complex (PPC) of soft wheat grain grown in North Kazakhstan, Karaganda, and West Kazakhstan regions, that is, the study region partially coincides with the location of these experimental plots. The researcher found that the best predecessor for spring wheat was black fallow and corn. In this study, the fallow predecessor also showed better results than wheat cultivation on wheat. Thus, the average yield of soft wheat of the Anel-16 variety on fallow was 22.6 dt/ha, and on wheat - 15.2 dt/ha. The researcher found that the Selyaninov hydrothermal coefficient ($r=0.92$) had a strong direct effect on the mass fraction of protein in soft wheat grain, and the amount of precipitation during the growing season had a weak, inverse effect. In this study, the influence of the average daily air temperature (r=0.35), the amount of precipitation during the growing season (r=0.31), and the Selyaninov hydrothermal coefficient (r=0.26) had a direct but insignificant effect on the amount of protein in the grain.

Finnish researchers, Hakala et al. [44], investigated the productivity of oats and barley in the context of climate change. They found that oats adapt better to weather changes, which contributes to an increase in oat crops in the world. Thus, oats, as a forage crop, is more promising than barley [45, 46]. Oats grow well in arid conditions, but special attention should be paid to the selection of varieties, especially when grown in cereal-legume mixtures [47, 48]. According to Latvian researchers, the increased average daily air temperature in May negatively affected the yield of oats (r=-0.6) [49]. The researchers also established a direct, average relationship between the amount of oat grain and the amount of monthly precipitation in May (r=0.468), but in July and August, precipitation had the opposite effect on the yield (r=-0.464 and -0.549). In this paper, the correlation analysis also showed the opposite, average effect of the average daily air temperature during the growing season on the amount of oat grain harvested (r=-0.49). A direct correlation of the average crop yield with total precipitation and HTC was established: r=0.49 and 0.51, respectively.

This research provides significant contributions and performance standards for newly developed indigenous crop varieties, which have been meticulously adapted to the distinctive agricultural circumstances of north-eastern Kazakhstan. In contrast to previous variety testing data, which may have predominantly utilised foreign introductions or obsolete Kazakh cultivars, the present study produces novel data that elucidate optimal production zones for various crops across the region. This research surpasses the scope of general regional classifications. Notably, North Kazakhstan Oblast is identified as the region with the highest spring wheat yield potential. Moreover, the research study measures the comparative benefits in yield offered by these novel cultivars, thereby furnishing crucial information to substantiate the adoption determinations of both farmers and policymakers [50-53].

Additionally, it performs an extensive examination of the impact that particular meteorological factors have on both the quantity and quality of the harvest, providing significant knowledge for the enhancement of production suggestions and predictions. Additionally, the research emphasises the favourable attributes of prospective new crop varieties including Anel-16, Ertis samaly, and Dostyk 15. This serves as "proof of concept" that substantiates ongoing financial commitments to Kazakh breeding initiatives that are customised to the nation's particular requirements. Significantly, this research offers a paradigm for decentralised, collaborative testing frameworks that effectively involve producers and capitalise on the infrastructure of pre-existing public research stations in various geographical locations. In essence, although not profoundly revolutionary, the research produces reliable, actionable data and insights that are highly beneficial in bolstering the expansion of the regional grains and forage industry. Moreover, they provide promising indications of ongoing innovation that is specifically designed to cater to the unique circumstances of Kazakhstan via public breeding initiatives [54, 55].

According to Bulgarian researchers, the cultivation of Sudangrass expands opportunities for the development of sustainable agriculture schemes, especially for arid regions with unevenly distributed precipitation during the growing season [56-58]. Despite this, there is very little scientific research on Sudangrass, most of the studies are conducted in Kazakhstan and Uzbekistan, but their focus differs from this paper. Thus, certain success has been achieved in the breeding and seed production of grain and forage crops in north-eastern Kazakhstan, but it requires improvement and further reorganisation. The study of the useful characteristics of new varieties of wheat, oats, and Sudangrass bred in the LLP "Pavlodar Agricultural Experimental Station" provides an understanding of the area in which further research needs to be conducted.

5. CONCLUSIONS

A study of the breeding and seed production activities of LLP "Pavlodar Agricultural Experimental Station" showed the prospects of cultivating new original varieties of spring soft wheat Anel-16, spring oats Ertis samaly, and Sudangrass Dostyk 15. Based on the conducted studies, these varieties were included in the State Register of Breeding Achievements in 2018 (Sudangrass) and in 2020 (wheat and oats), recommended for use in the Republic of Kazakhstan. These agricultural crop varieties are recommended for cultivation in the north-eastern part of the country. It has been shown that the North Kazakhstan Region has the most favourable conditions for the cultivation of spring wheat, and the Pavlodar Region - for oats.

In 2017-2019, the average yield of wheat of the Anel-16 variety significantly differed by regions ($LSD_{0.5}$ = 2.6): in the North Kazakhstan Region it was 26.6 dt/ha (on fallow) and 18.4 dt/ha (on wheat); in Akmola - 23.5 and 15.1 dt/ha; in Pavlodar - 15.3 and 11.2 dt/ha, respectively. The following average grain quality indicators were obtained: weight of 1000 seeds - 37 g, protein content - 12.6%, gluten content - 30.8%. A direct average effect (r=0.48) of average daily air temperatures on wheat yield, and a direct but insignificant effect of precipitation (r=0.3) and HTC (r=0.25) were established, and these factors directly but insignificantly influenced the protein content in the grain. The yield of oats of the Ertis samaly variety in the study period ranged within 123-21.4 kg/ha, the average weight of 1000 seeds was 35.7 g, protein content - 10.9%, and hull content - 26%. It was found that the air temperature had an inverse, average effect on the yield of oats (r=-0.49), and precipitation and HTC had a direct, average effect: r=0.49 and 0.51, respectively. The yield of herbage of the Dostyk 15 variety of Sudangrass in the study region averaged 101.9 dt/ha, and dry weight - 39.7 dt/ha. The average protein content in herbage - 15.5%, and the fibre content - 29%. The average daily air temperature had an inverse, average effect (r=-0.6) on the yield of herbage of this crop, and the amount of precipitation and HTC had a direct and insignificant effect (r=0.22 and 0.3). The air temperature had an average, inverse effect (r=-0.6) on the protein content, while the amount of precipitation and HTC - direct, average effect (r=0.53 and 0.56).

In north-eastern Kazakhstan, the research findings improve agricultural practices by shedding light on the adaptability and productivity of newly developed crop varieties. This information assists agricultural practitioners in choosing the most appropriate crops for the unique conditions of their regions, thus maximising both output and quality. The results of this study can provide valuable insights for future breeding initiatives by identifying the most desirable and adaptable traits in wheat, oats, and Sudangrass, which are also sensitive to changes in soil and climate. This may result in the creation of crop varieties that are more resilient and produce greater yields. The potential economic ramifications of this research are substantial. Achieving greater productivity is possible for farmers through the implementation of informed selection and breeding practices, which enhance quality and increase crop yields. This may result in increased income for farmers and contribute to the agricultural sector's overall economic expansion in Kazakhstan. Furthermore, the advancement of climate-adapted and more efficient agricultural varieties can result in cost and resource savings, thereby augmenting the economic advantages.

In summary, the research endeavour centred on the assessment of the efficacy of Kazakh-bred varieties, specifically Dostyk 15 Sudangrass, Anel-16 wheat, and Ertis samaly oats, throughout five discrete areas situated in the northeastern part of Kazakhstan. The study examined a range of variables, such as quality, yield, resistance to diseases, and tolerance to drought, to provide insight into the adaptability of these factors to the varied agro-climatic conditions prevalent in the area. Although the results offer significant implications for seed producers and farmers in northeastern Kazakhstan, it is indisputable that additional investigation is required to completely exploit the capabilities of these cultivars. Further research in the fields of economics, quality evaluation, agronomy, and their efficacy across different cropping systems will be crucial to facilitate the effective assimilation and sustainability of these innovative Kazakh varieties. By adopting this comprehensive approach, a more holistic comprehension of their efficacy in various geographical regions can be achieved, thereby fostering the sustainable development of the agricultural industry in Kazakhstan.

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