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Influence of water-saving irrigation technology on the yield of grain crops in the northern region of Kazakhstan

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ABSTRACT

The choice of irrigation method depends on the crop, soil, terrain, hydrogeological and climatic conditions, as well as the level of agricultural production development. Sprinkler irrigation has traditionally been used in the northern regions of Kazakhstan due to the natural and climatic conditions of the region and the composition of cultivated crops. The purpose of this research was to study the impact of water-saving irrigation technology on the yield of grain crops in the northern region of Kazakhstan. Experimental studies were conducted in 2022 at an experimental station located in the Akkayin District of the North Kazakhstan region. The main objects of the study were Astana spring wheat, Sabir spring barley, and Dauren spring triticale. It was planned to use a sprinkler irrigation system with a modern sprinkler machine for the irrigation of crops. Control fields without irrigation were used to analyze the effect of irrigation. It was established that the main effect of irrigation can be observed in an elevation in the productive bushiness of crops in irrigated areas, leading to a yield increase. The yield of spring wheat under irrigation was 29.3 c/ha, while did not exceed 24.9 c/ha on a plot without irrigation. The yield of spring barley under irrigation was 46.9 c/ha, whereas was at the level of 34.4 c/ha without irrigation. Spring triticale had a yield of 41.6 c/ha when irrigated, while did not exceed 28.0 c/ha without irrigation. The irrigation effect can be noted as significant based on these results.

Keywords: Grain crops, Water-saving, Irrigation technology, Yield.
Article type: Research Article.

INTRODUCTION

Irrigation ensures the stability of the crop yield (Malakhov *et al.* 2022). Several studies have been devoted to applying innovative water-saving irrigation systems in various soil and climatic conditions (Saltanat *et al.* 2015; Balgabaev *et al.* 2020; Kalashnikov *et al.* 2022). Gorodnichev & Kostovarova (2011), reported the effect of irrigation on the yield of winter wheat on the slightly-saline sierozemic-meadow soils, concluding that when sprinkling, the yield of wheat of the Kroshka variety increased by 8-20% compared to surface irrigation along the furrow by 8-20% leading to a drop in the irrigation rate by 2.5-3 times. Koibakova & Amanbaeva (2015) presented the results of field research on the development of resource-saving technology for the irrigation of grain crops in conditions of irrigation water shortage. It was established that under conditions of water resources shortage on light chestnut soils of the Pavlodar region when cultivating spring wheat, it was economically feasible to reduce the irrigation rate by 15-20% in the initial vegetation period – the tillering phase. Crop losses in the tillering phase amount to 8-10% of the optimal option. In the studies, the highest yield of 3.8 ton ha^{-1} was obtained by option 1 (watering 5 times), where the optimal water balance

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of the soil was maintained throughout the vegetation period, once the irrigation rate was 1,450 m^3 ha^{-1}. The lowest yield was obtained in the group where the lowest irrigation rate of 850 m^3 ha^{-1} per season was applied, and, accordingly, the lowest yield of 2.5 ton ha^{-1} was obtained. In the four seasons of 1998-2001, Shreidi (2019) conducted a field experiment to study the effectiveness of cultivation of some triticale lines in comparison with the most dominant grain crops in the country, i.e., wheat and barley, in rain-fed and irrigated desert areas. The results obtained showed that the average yield of triticale under irrigation conditions was 7.0-9.0 ton ha^{-1}, while 6.0, 6.71, and 6.58 ton ha^{-1} for barley, durum, and soft wheat, respectively. Five irrigation regimes were used to study the effect of micro-irrigation with different levels of irrigation on winter wheat grain yield and greenhouse gas emissions in the North China Plain. Additional irrigation brought the soil moisture in the 0-40 cm profile to 65% (K65), 70% (K70), 75% (K75), 80% (K80), and 85% (K85) of the field capacity (FC). The research results showed that a 96% elevation in grain yield was observed for K75 compared to K65, K70, and K85 irrigation regimes respectively, mainly due to an upraise in the number of grains and the mass of 1,000 grains. Compared to the K80 and K85 options, K75 exhibited the most noticeable effect on the instability of the carbon, nitrogen, and moisture content in the soil, which resulted in a decline in accumulated nitrogen emissions in the soil (5.15-15.65%) and the CH_4 content (6.07-44.07%). It has also reduced the potential for global warming (6.17-19.53%) (Zhen *et al.* 2023). Agricultural production in Kazakhstan is conducted in difficult climatic conditions, since 70% of the area of agricultural land is located in the zone of insufficient and unstable moisture, and also in the steppe and dry-steppe zones, where every second and third year is dry. The shortage of water resources in Kazakhstan will amount to 23 km^3 of cultural production by 2030, enhancing the economic risks associated with crop losses due to drought. The technologically-outdated irrigation systems remain a serious barrier. Water losses often reach 40%. Such indicators are unacceptable for water-deficient in Kazakhstan (Bekezhanov, *et al.* 2021; Yessimbek *et al.* 2022; Yesmagulova *et al.* 2023). The choice of irrigation method depends on the crop, soil, terrain, hydrogeological and climatic conditions, and the level of agricultural production development. Sprinkler irrigation has traditionally been used in the northern regions of Kazakhstan (Kalashnikov *et al.* 2020). This method of irrigation is preferable due to the climatic conditions of the region and the composition of cultivated crops. (Alberto *et al.* 2014) studied corn and rice with dry sowing, grown using a sprinkler system, as an alternative to typical rice cultivation on puddled and moist soil. They concluded that such a study makes it possible to create a more efficient irrigation schedule, which is an excellent opportunity to maximize the irrigation water supply. (Delgado *et al.* 2021) pointed out that the most effective management methods for elevating yields in a cost-effective way include the narrow row spacing and optimal nitrogen application. It was concluded that the yield of silage and grain in sprinkler systems increases due to the use of thin rows with a higher density of plants. The purpose of this research was to study the impact of water-saving irrigation technology on the yield of grain crops in the northern region of Kazakhstan.

MATERIALS AND METHODS

Experimental site

Experimental studies were conducted at an experimental station located in the Akkay in District of the North Kazakhstan region (Fig. 1). The characteristics of the soils were as follows: ordinary carbonate, heavy, loamy, chernozem with neutral and slightly alkaline reactions.

Fig. 1. Location of the experimental site.

Climate

The average long-term observation data of the Kiyaly weather station were used to characterize the climatic conditions of the territory under consideration.The climate of northern Kazakhstan is arid, sharply continental. It is characterized by low rainfall and extremely unstable weather conditions. The climate of the zone is arid with moderate heat. The average amount of precipitation ranges from 240 to 330 mm per year. The vegetation period ranges from 136 to 137 days, and the hydrothermal coefficient (HC) is about 0.8-0.7. A significant excess of positive temperatures led to the early appearance of perennial, wintering, as well as some annual weeds (sedge, shepherd's purse, dandelion, stickseed, etc.). However, cereal weeds appeared much later, leading to the need to adjust the technology of cultivating crops in spring. The limited amount of precipitation in winter and at the beginning of the spring caused a good/high level of soil moisture after a snowfall. The content of productive moisture in the meter layer of soil for deposits was 142-158 mm, while 88-92 mm for wheat stubble, and 105-112 mm for cold backgrounds. Thus, 2022 can be characterized as a favorable period for the cultivation of major crops. However, crops sown under the recommended agrotechnical conditions were provided with optimal moisture in critical phases of demand. The temperature background was moderate, and the hydrothermal coefficient of the vegetation period of crops in the current season corresponded to favorable growing conditions.

Soil properties

Analysis of the main chemical parameters showed that the soil at the experimental site contained an average of 36.45 mg kg^{-1} nitrate-nitrogen ($N\text{-}NO_3$), 51.05 mg kg^{-1} mobile phosphorus (P_2O_5), 703.8 mg kg^{-1} exchangeable potassium (K_2O), 4.88% humus and pH 5.5. Loess-like loams and eluvium of carbonate clays serve as soil-forming rocks. Saline chernozems develop on loess-like loams, and a homogeneous complexness cover of carbonate medium-humus chernozems develops on the eluvium of carbonate clays. All loams are enriched with calcium carbonates, and the presence of gypsum is insignificant. The composition of absorbed bases differs little from ordinary chernozems in terms of humus content and gross reserves of mineral nutrition elements. However, it differs from them in the content and distribution of salts: the upper horizon boils violently from hydrochloric acid, and the lower part of the profile contains easily soluble salts. Their clay composition causes poor water permeability, high water retention capacity, and strong swelling in humid conditions. Landscapes are characterized by the absence of forests, chernozem carbonate soils, and the occurrence of Neogene clays close to the surface, as a result of which there is a coherent structure, compaction, and fracturing. Carbonate chernozems swell strongly when wet, and they form cracks through which air penetrates when dry. These soils combine the negative properties of both carbonate (their poor structure) and glossy (uneven color of the humus horizon, and hence the distribution of humus). Therefore, from a production point of view, carbonate medium-humus chernozems are less fertile than ordinary medium-humus and carbonate chernozems.

Research design and studied cultures

A survey of experimental sites was conducted and field experiments were laid. The experiment was laid on May 13, 2022, with a 3-fold repetition. The harvesting was carried out on September 02, 2022. The area of one experimental site was 80 m^2 with a width of 8 m and a length of 10 m. The placement of options in the experiments was randomized with sequential arrangement in repeats. The diagram of the experiment is shown in Fig. 2.

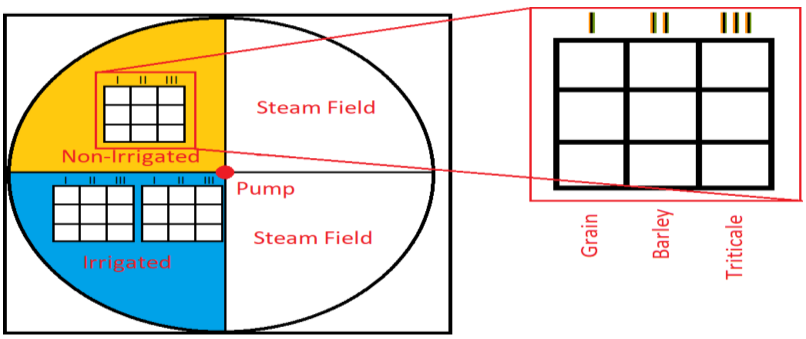

Fig. 2. Diagram of the experimental section.

The main objects of this study were (i) Astana spring wheat; (ii) Sabir spring barley; and (iii) Dauren spring triticale. A brief description of the studied cultures is presented below:

1.Spring soft wheat of the Astana variety can be characterized as a medium-early type of maturation with high stem alignment, friendly maturation, and resistance to diseases and pests. The yield of the variety, determined by pure steam as a result of competitive variety testing, was 15.8 c ha^{-1}. The drought resistance of this variety is high, it has high physical and milling qualities of grain. The contents of raw gluten, protein, the mass of 1,000 grains in the grain and the vitreous solid are 35.9%, 16.1%, 31.9 g and 62% respectively. The best precursor of the variety is pure steam.

2. Spring barley of the Sabir variety belongs to the type of chickpeas. The ear is double-rowed, loose, erect, spiny, cylindrical in shape, yellow with anthocyanin color. The grains are large and yellow, and the mass of 1,000 grains ranges from 45 to 60 g. Sabir barley belongs to the middle-ripening types and has a vegetation period of about 72-77 days. It has an economically valuable complex. It is also drought-resistant, and responsive to moisture. The average yield is 35 kg ha^{-1}.

Spring triticale of the Dauren variety is an erythrospermum with a white spinous ear and red grains. The vegetation period is a medium-ripened variety. In terms of yield, the variety is high-yielding. It can produce from 5 to 8 (or more) quintals per 1 ha in the climatic conditions of northern Kazakhstan. The potential yield of the variety is high – up to 45-50 c/ha. It has the following properties: the grain is vitreous; the mass of 1,000 grains ranges from 35 to 45 g; the vitreousness is from 65 to 80; the protein content in the grain is about 12.5-13.0%; the starch content in the grain starts from 60%; It is resistant to powdery mildew, dusty smut and types of rust.

Irrigation system

The capillary use of groundwater in the area under consideration is minimal due to the large depth of their occurrence. In 2022, the shortage of water consumption was observed only in the second and third 10-day periods in May and the first 10-day period in June. There is a surplus of water consumption in the remaining months due to the large amount of precipitation. We planned to use a sprinkler irrigation system with a modern sprinkler machine for the irrigation of crops that provides fine sprinkling with low rain intensity and does not adversely affect the soil cover (Fig. 3).

Fig. 3. Sprinkler irrigation system used at the experimental site.

Irrigation of grain crops was carried out by a Zimmatic sprinkler with a radius of 324 m in the experimental plots. Watering was carried out considering the current shortage of water in the field and the technical characteristics of the sprinkler machine. The control group was an option without irrigation. The early spring moisture sealing was carried out with BS-15 spring harrows. As weeds appeared, intermediate and pre-sowing treatment was carried out before sowing the experimental plots. Pre-sowing treatment was carried out to the depth of seeding before sowing. Sowing of grain crops was carried out with a seeder SZS-2.1 with tabs. There were zoned varieties as control and experimental varieties of wheat, barley, and triticale. The seeding rates used and the sowing dates were selected by the recommended ones for the research area. The soil was rolled with a KKZ-9.2 sealing roller after sowing. The paths and dividing and protective strips had been treated with a small-sized cultivator during the germination period. A closed network of pipelines was used to supply water to sprinklers, eliminating losses during its transportation to machines. Pumps with electric motors were used to take water from a water source, eliminating contamination and clogging of water. Wet wells were provided in areas of low relief for the discharge of wastewater from the pipeline network of the irrigation system at the end of the irrigation period.

The technology of shallow sprinkling allowed watering with the saturation of the necessary amount of water only of the root layer. Such irrigation eliminated deep filtration of irrigation water, thereby preventing the rise of deep-lying (more than 3 m in automorphic mode) groundwater and its closure with irrigation water. This mode prevents secondary salinization of the upper root-inhabited soil horizons. The timing and norms of irrigation were assigned depending on the shortage of water for consumption and the technical characteristics of the sprinkler machine, which allowed the use of 8 mm day^{-1} or 80 m^3 ha^{-1}. In 2022, the shortage of water for consumption was observed only in the second and third weeks of May and the first week of June. There was an excess of water for consumption in the remaining months, due to the large amount of precipitation. The shortage of water for consumption of 80 m^3 ha^{-1} occurred on May 23. The first watering of 80 m^3 ha^{-1} was carried out on this day. The shortage of water for consumption of 160 m^3 ha^{-1} occurred on May 31. The second watering of 80 m^3 ha^{-1} was carried out on this day. The third watering was carried out on June 10 at the rate of 54.7 m^3 ha^{-1}. To do this, the mode of movement of the sprinkler machine was changed using a timer installed in the control cabinet. The timer was set to 80%. The irrigation regime is presented in Table 1.

Table 1. Irrigation regime.

Irrigation date	May 23	May 31	June 10	Watering rate/Water deficit
Irrigation rate (m^3/ha)	80	80	54.7	214.7

Data analysis

The structural analysis of the yield of the studied crops in the phase of full ripeness of grain was carried out by the methodological guidelines for the study of the world collection of the genebank of genetic resources of plants in the All-Union Research Institute of Plant Breeding. Crop accounting was carried out by mowing the landfill of the accounting area with a ZVN-6 harvester, selecting and threshing rolls, and recalculating yield data to a standard of 14% humidity and 100% grain purity.

The irrigation norm, or water consumption deficit, is the amount of water that needs to be supplied to 1 ha of an irrigated field during the vegetation period to get the planned yield. The irrigation rate depends on the timing and duration of the vegetation period, biological characteristics of cultivated crops, and climatic soil-reclamation conditions of the irrigation area. The irrigation rate was calculated according to formula 1:

$$Mn = \Delta Ev = Ev-(Vp + 10 \times Rv + G) \quad \textbf{(1)}$$

where Mn = irrigation rate (m^3 ha^{-1});
ΔEv = water consumption deficit during the vegetation period, (m^3 ha^{-1});
Ev = total water consumption (m^3 ha^{-1});
Vp = initial moisture reserve in the soil (m^3 ha^{-1});
Rv = precipitation during the vegetation period (mm);
G = capillary use of groundwater (m^3 ha^{-1}).

The initial reserves of moisture in the soil were established by the accumulation and preservation of non-vegetative precipitation in the soil according to the actual average annual climatic data and are calculated according to formula 2:

$$Vp = 10 \times Rn \times \mu \qquad \textbf{(2)}$$

where Rn = the amount of non-vegetative precipitation, mm;
μ = the coefficient of precipitation utilization, (μ= 0.4 of the water-holding capacity of soils).
The water-holding capacity of soils is determined according to formula 3:

$$W = 100\ \text{ɣ}h\beta n \qquad \textbf{(3)}$$

where W = the water-holding capacity of soils;
ɣ = the volume weight of the soil (ton m^{-3});
h = the depth of the calculated layer (m);
βn = FC (%).

The analysis of the obtained data was carried out using the method of determining the significance of differences between the samples according to the LSD (least significant difference).

RESULTS AND DISCUSSION

Structural indicators of productivity of grain crops depending on the irrigation rate

Structural analysis of spring wheat yield

The structural analysis of the crop allows us to identify the features of the actual yield formation. It fully reflects the dependence of yield on many factors, including the accumulation of vegetative mass of plants, stem density, grain size, ear length, number of spikelets, and the number of grains in them (Kenebayev *et al.* 2022; Rakymbekov *et al.* 2023; Nasiyev & Dukeyeva 2023). A structural analysis was carried out in the experiment on the development of irrigation technology for grain crops and the subsequent calculation of average indicators. Thus, the indicators of the structure of wheat plants in the experiment were influenced by the use of irrigation, as well as by the irrigation rate per 1 ha of sowing. The studied variety of spring wheat was the Astana variety, zoned in this region, and is the standard for the North Kazakhstan region, fully reflecting the features of obtaining good harvests under favorable growing conditions, and reducing productivity in severe drought. The variety belongs to the early ripening group. According to the results of the analysis, it can be concluded that the obtained biological yield of spring wheat is highly correlated with such indicators as the number of productive stems, productive bushiness, the number of spikelets in the ear, and the grain weight per 1 ear. According to the data obtained, it can be seen that the irrigation norms did not affect the plant density at the time of harvesting. Thus, the number of plants was 198.5 pcs/m^2 in the option without watering NP0, and 193.0 pcs/m^2 in the NP2 option (Table 2). There were also no special differences in the weight of the sheaves. The average sheaf weights on the option without watering were 675 and 625 g/m^2 on the NP2 option. The irrigation norms did not affect the plant height indicators and averaged 74.0 cm on the option without irrigation and 72.48 cm on NP2. The number of productive stems in the accounting area showed some growth.

Thus, it was 300.0 pcs/m^2 with the number of stems under control. The quantity of NP2 was in the range of 332.4 pcs/m^2, with a difference from the control of 32.4 pcs/m^2. The number of unproductive stems according to the experiment options, in the form of a fitting and a squat, was practically absent. The productive bushiness at the control was at the level of 1.5, which is within the standard indicator for this variety of spring wheat on dryland. However, it was already up to 1.72 at the watering rate 2. The length of the ear according to the options was in the range of 5.68-6.06 cm. The average length was 5.98 cm in the NP0 option and 5.83 cm in the NP2 option. According to the number of spikelets in the ear, there was not a large increase, so with the indicator on the control of 11.04 pcs., their number on the options with watering was 11.31 pcs, depending on the watering rate. It should be noted that the weight of grain from the ear was 0.85 g/ear with the number of grains in the ear on the option without watering (23.5 pcs). The NP2 option with an indicator of the number of grains per ear (22.99 pcs), and grain weight (0.92 pcs/ear), yielded to the control by 2.5% in terms of the number of grains in the ear, and 8.2%

in terms of grain weight. The mass of 1,000 grains is the basis for the fulfillment of grain, however, there were no significant differences in this indicator, and it was in the range of 35.4, 34.8, and 36.3 g, respectively. Therefore, by analyzing the structural indicators, it can be stated that they influenced the formation of the harvest according to the experiment options.

The yield at the control was 25.39 c/ha, with a grain weight of 253.48 g/m^2. At the rate of NP2, which exceeded the options for most indicators, it was 30.7 c/ha, with the amount of grain as 307.03 g/m^2. The excess of control according to irrigation standards was in the range of 3.8-5.3 c/ha. Thus, biological yield to some extent characterizes the yield obtained on the experimental options, and at the same time, the data obtained in the first year do not yet give a complete picture but have a pronounced tendency for further study.

Table 2. Indicators of the spring wheat yield structure in the experiment on the study of irrigation standards, 2022.

Culture, Variety	Sowing period	NP	Rept.	Plants number, (pcs/m^2)	Sheaf weight, g/m^2	Plant height (cm)	Number of productive stems, (pcs/m^2)	Productive bushiness	Ear length (cm)	Number of spikelets per ear, (pcs)	Number of grains per ear (pcs)	Grain weight per 1 ear (g)	Grain weight (g/m^2)	Weight of 1,000 grains (g)	Biological yield (c/ha)
Wheat, Astana	13.05	NP-0	1	196.00	700.0	79.58	295.00	1.50	6.06	11.00	23.53	0.85	250.75	36.00	25.17
	13.05	NP-0	3	201.00	650.0	68.43	305.00	1.50	5.90	11.08	23.52	0.84	256.20	34.80	25.60
	Average			198.50	675.0	74.01	300.00	1.50	5.98	11.04	23.52	0.85	253.48	35.40	25.39
	13.05	NP-2	1	190.00	600.0	75.42	314.00	1.65	5.68	11.47	22.63	0.96	301.80	36.60	30.18
	13.05	NP-2	3	196.00	650.0	69.53	350.84	1.79	5.99	11.14	23.36	0.89	312.25	36.00	31.23
	Average			193.00	625.0	72.47	332.42	1.72	5.83	11.31	22.99	0.92	307.03	36.30	30.71

Structural analysis of the spring barley harvest

Watering did not significantly affect the number of plants per 1 m^2. On average, the number of plants in the options was at the level of 235-244 pcs/m^2 (Table 3). One of the indicators characterizing the responsiveness of the variety to the applied agrotechnical techniques is the number of productive stems per unit area (Makenova *et al.* 2023; Nokusheva *et al.* 2023; Dutbayev *et al.* 2023). Thus, at the control, their number was 443.5 pcs/m^2, with a fairly high presence of unproductive ones in the sample, in the form of underwood of 1.5 pcs/m^2, and underbrush of 6.0 pcs/m^2. The irrigation option NP2 provided the number of stems as 574 pcs/m^2, exceeding the control by 130.5 pcs/m^2. Following the change in the general bushiness, the productive bushiness had also been changing, which had also been changing depending on the watering rate.

The bushiness was at the level of 1.82 at the control, while the irrigation rate was 2, with a value of 2.38. It should be noted that such indicators as the number of spikelets in the ear, as well as grains in the ear, had been changing slightly. Thus, with the number of spikelets in the ear at the control of 8.18 pcs, and the number of grains in the ear – at 15.87 pcs/ear, the number of options with watering ranged up to 8.29 pcs/ear – by the presence of spikelets, and up to 16.78 pcs/ear – by the presence of grains in the ear. No significant changes are noted in the length of the ear. The watering rate of 2 was at the control level – 6.49 cm.

The weight of 1,000 grains had been changing depending on the applicable irrigation rate. This indicator was 49.53 g at the control, while 50.6 g at NP2, which is 1.1 g higher. In general, the indicators of the crop structure reflect the reasons for obtaining a higher yield on irrigation technology application options. Thus, the highest productivity of spring barley was obtained on the NP2 option – 46.2 c/ha, and 462.1 g/m^2 with a grain weight of 1 m^2. The excess of control was 11.2 c/ha. The yield at the control was at the level of 35.03 c/ha. Irrigation efficiency for spring barley, expressed in obtaining a larger yield on options with irrigation, in 2022 was 11.2 centners/ha, respectively, for NP2.

Structural analysis of spring triticale yield

The analysis of the yield structure for spring triticale also showed changes depending on the irrigation norms. Thus, the application of irrigation norms had an impact on some plant indicators, such as plant height, the number of productive stems, productive bushiness, as well as the length of the ear, the number of spikelets and grains in the ear, the weight of grain per ear, and in general on the overall productivity according to the experiment options. Notably, such an indicator as the mass of 1,000 grains reacted poorly to the application of irrigation standards.

Table 3. Indicators of the yield structure of spring barley in the experiment on the study of irrigation standards during 2022.

Culture, Variety	Sowing period	NP	Rept.	Plants number, (pcs/m²)	Sheaf weight, g/m²	Plant height (cm)	Number of productive stems, (pcs/m²)	Productive bushiness	Ear length (cm)	Number of spikelets per ear, (pcs)	Number of grains per ear (pcs)	Grain weight per 1 ear (g)	Grain weight (g/m²)	Weight of 1,000 grains (g)	Biological yield (c/ha)
Sabir Barley	13.05	NP-0	1	254.00	1200.0	70.56	457.00	1.80	6.18	8.48	16.65	0.78	356.46	48.10	35.65
	13.05	NP-0	3	234.00	880.00	55.79	430.00	1.84	6.82	7.88	15.10	0.80	344.00	50.96	34.40
	Average			244.00	1040.0	63.18	443.50	1.82	6.50	8.18	15.87	0.79	350.23	49.53	35.03
	13.05	NP-2	1	240.00	950.00	59.42	570.00	2.37	6.60	7.45	15.27	0.79	450.30	51.50	45.00
	13.05	NP-2	3	241.00	900.00	62.35	578.00	2.39	6.39	7.80	15.69	0.82	473.96	49.70	47.40
	Average			240.50	925.00	60.89	574.00	2.38	6.49	7.63	15.48	0.80	462.13	50.60	46.20

The values varied in the range of 220.5 mg/m²-219.5 pcs/m² according to the results of observations of the number of plants per 1 m². There were no differences (Table 4). The weight of the sheaf according to the options exhibited a slight increase. If the weight was 725 g at the control, then the NP2 watering was 925 or 200 g more than at the control. The height of the plant on watering options was in the range of 83.1-87.9 cm, which is higher than the control (75.8 cm) by 7.3-12.1 cm. The number of productive stems had been changing depending on the watering rates. Thus, if the number of productive stems on the control was 269.5 pcs/m², then it exhibited a slight increase with NP2 and amounted to 280 pcs/m². Noteworthy, the productive bushiness increased depending on the number of productive stems according to the experiment options. The coefficient was 1.22 at the control, and 1.27 at NP2. There was some increase in the length of the ear.

The control was at the level of 6.71 cm. The irrigation option NP2, with a value of 7.76 cm, exceeded 1.05 cm. An elevation in the number of spikelets and grains in the ear should also be noted. The number of spikelets and grains in the ear at the control reached 14.11-25.72 pcs. The following differences according to the norm of NP2 were 1.7 and 8.4 pieces according to the number of grains in the ear respectively. The weight of grain per 1 ear depends on the number of spikelets and grains in the ear. The weight of grain per ear at the control was 1.24 g, and 1.57 g in NP2, with an excess of 0.33 g. The mass index of 1,000 grains had been changing quite slightly depending on the applicable irrigation standards. Thus, the average weight of 1,000 grains in the control was 45.95 g, and the value reached 47.4 g in the NP2. Thus, the analysis of the crop structure allowed us to substantiate the experimental data obtained, as well as the elements of increasing yields during irrigation. By a yield of 30.65 c/ha at the control, and the amount of grain (306.61 g/m²), NP2 by a yield of 43.82 c/ha, exceeded the control by 13.2 c/ha. The irrigation efficiency in 2022 on spring triticale was quite high (43.0%) according to NP2. If we compare yields concerning irrigation norms, it should be noted that there are no special differences.

Yield of grain crops depending on the irrigation rate

Watering has influenced both the vegetation of plants and their growth and development, as well as the formation of productive organs and, ultimately, yield. Therefore, emphasis was placed on each grain crop, because they reacted differently to the main factor. The yield of spring wheat of the Astana variety, depending on the options, was in the range of 24.9-29.4 c/ha (Table 5). However, if the yield was 24.9 c/ha at the control (without watering), then it was 29.4 c/ha at watering at a rate of 80% field capacity, i.e., the difference was 3.8-4.4 c/ha, respectively. Thus, a significant difference was obtained between control and irrigation, $LSD_{0.95}$ was 1.27 c/ha. The increase in yield during watering was influenced by productive bushiness, the number of productive stems, the number of spikelets in the ear, the number of grains in the ear, and the grain weight per 1 ear (Table 5). A higher yield of 29.5 c/ha was obtained with a watering rate of 80% field capacity. However, the difference of 0.7 c/ha is insignificant, since $LSD_{0.95}$ is 1.27 c/ha. This suggests that the weather and climatic conditions of the current year may have leveled this factor due to heavy precipitation in the summer. In addition, since this variety is rain-fed, it is probably less adapted to changes in irrigation standards.

Table 4. Indicators of the yield structure of spring triticale in the experiment on the irrigation standards study during 2022.

Culture, Variety	Sowing period	NP	Rept.	Plants number, (pcs/m^2)	Sheaf weight (g/m^2)	Plant height (cm)	Number of productive stems, (pcs/m^2)	Productive bushiness	Ear length (cm)	Number of spikelets per ear (pcs)	Number of grains per ear (pcs)	Grain weight per 1 ear (g)	Grain weight (g/m^2)	Weight of 1,000 grains (g)	Biological yield (c/ha)
Triticale Dauren	13.05	NP-0	1	224.0	600.0	77.5	282.0	1.25	6.18	13.81	24.75	1.09	307.38	45.30	30.70
	13.05	NP-0	3	217.0	850.0	74.2	257.0	1.18	7.24	14.41	26.70	1.39	305.83	46.60	30.60
	Average			220.5	725.0	75.8	269.5	1.22	6.71	14.11	25.72	1.24	306.61	45.95	30.65
	13.05	NP-2	1	221	1050	89.1	285.0	1.28	7.58	15.71	34.97	1.55	441.75	47.60	44.18
	13.05	NP-2	3	220.0	800.0	77.1	275.0	1.25	7.95	15.84	33.24	1.58	434.50	47.20	43.45
	Average			220.5	925	83.1	280.0	1.27	7.76	15.77	34.10	1.57	438.13	47.40	43.82

The Sabir barley variety showed a high yield, in the range of 34.5-46.9 c/ha. Thus, the average yield on the control was 34.5 c/ha, and 46.9 c/ha on the option with an irrigation rate of 80% field capacity. The use of irrigation contributed to an increase in yield at 80% by 12.4 c/ha. These increases are significant at $LSD_{0.95}$ 2.4 c/ha. Consequently, the irrigation factor made it possible to get a significant increase in the weather and climatic conditions of 2022.

Obtaining a significant increase from irrigation in comparison with the control is shown by the data of the analysis of the crop structure (Table 2). Thus, the indicators of productive bushiness, the number of productive stems, the weight of grain per ear, and the weight of 1,000 grains were in the irrigation options. To some extent, such indicators as the length of the ear, and the number of spikelets in the ear also exhibited an impact. Obtaining a higher yield of 4.8 c/ha on an option with an irrigation rate of 80% field capacity indicates the responsiveness of this variety to the moisture factor. In addition, confirmation of this increase is the quality indicators of productive stems, the weight of grain per ear, as well as the weight of 1,000 grains. The yield indicators of the spring triticale of the Dauren variety in the experiments were in the range of 28.0-41.6 c/ha. There was a yield of 28.0 c/ha without irrigation (control), and a yield of 41.6 c/ha was obtained on irrigation at 80% field capacity. A significant increase ($LSD_{0.95}$ 2.63 c/ha) of 13.6 c/ha was obtained. This increase in yield during irrigation was influenced by indicators of the structure of plant analysis (Table 3) as the mass of sheaves from 1 m^2, productive bushiness and the number of productive stems, the length of the ear, the number of spikelets and grains in the ear, as well as the grain weight per one ear and the weight of 1,000 grains. Summing up the analysis of the grain crop data, we can make a preliminary conclusion that spring wheat, spring barley, and triticale have a certain positive responsiveness to irrigation.

Table 5. Yield of grain crops (spring wheat, barley and triticale) in the irrigation hospital, depending on the irrigation rate during 2022.

Culture, Variety	Sowing dates	NP	Rept	Yield, dt/ha	Grain moisture during harvesting (%)	Yield at 14% humidity	Increase, +/-
Wheat, Astana	May 13, 2022	0	av.	24.21	11.50	24.92	-
		80% FC2	av.	28.59	11.70	29.35	+4.4
					$LSD_{0.95}$	1.27	
Barley, Sabir	May 13, 2022	0	av.	32.96	10.13	34.45	-
		80% FC2	av.	45.00	10.43	46.88	+12,4
					$LSD_{0.95}$	*2.40*	
Triticale, Dauren	May 13, 2022	0	av.	27.25	11.63	28.01	-
		80% FC2	av.	40.29	11.20	41.60	+13.6
					$LSD_{0.95}$	2.63	

CONCLUSION

The main results obtained in the course of current research can be summarized as follows. Agrotechnics for the cultivation of grain crops has been developed, which is complemented by irrigation technology by sprinkling grain crops on irrigated lands of northern Kazakhstan. Control fields without irrigation were used to analyze the effect of irrigation. It is established that the main effect of irrigation can be observed through an increase in the values of productive bushiness of crops in irrigated areas, leading to a yield increase. The yield of spring wheat under irrigation was 29.3 c/ha, and it did not exceed 24.9 c/ha on a plot without irrigation. The yield of spring barley under irrigation was 46.9 c/ha and was at the level of 34.4 c/ha without irrigation. Spring triticale had a yield of 41.6 c/ha when watered, and it did not exceed 28.0 c/ha without irrigation. The irrigation effect can be noted as significant based on these results.

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