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Influence of Sowing Dates and Seeding Rates of Spring Triticale (Triticosecale Wittmack) on Yields and Crop Structure Elements

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ABSTRACT

One of the most important areas of development of the agro-industrial complex at the present stage is obtaining high and sustainable grain yields. Spring triticale plays a significant role in solving this problem, as one of the most productive grain crops. In this case, adjusting the seeding rate is an affordable and effective method for successfully managing the crop's productivity. The purpose of the study is to substantiate the optimal sowing dates and seeding rates of spring triticale in the zone of ordinary chernozems of Northern Kazakhstan, providing a maximum yield of grain products. The innovation of this article is that it presents data on the study of sowing dates and seeding rates of non-traditional spring triticale culture of two varieties – Dauren and Rossika in the conditions of the North Kazakhstan region. The results of the average yield of spring triticale varieties depending on the sowing period, seeding rates, and meteorological indicators of the growing season of 2019-2021 were provided. It was concluded that the most optimal sowing period is the end of the second ten days – the third ten days of May, and the optimal seeding rate is in the range of 4.0-5.0 million germinable seeds per hectare.

1. INTRODUCTION

The timing of sowing and seeding rates are of paramount importance in the complex of agrotechnical measures aimed at increasing the yield and ultimately the gross yield of spring cereal crops [1-3]. The correctly chosen sowing period increases the efficiency of all methods of the farming system. In some years, the timing of sowing affects the harvest more significantly than the most important elements of agricultural technology – fertilisers, predecessors, and tillage [4]. According to the experimental data of the North Kazakhstan Agricultural Experimental Station, the use of optimal sowing dates and seeding rates, which is individual for each variety, provide, without additional material costs, an increase in yield from 2 to 6 or more metric centners per hectare [1]. The variety and the corresponding sowing period are the cheapest means of obtaining a stable harvest [5].

Spring triticale is an unconventional grain crop grown for the first time in the conditions of Northern Kazakhstan and recommended for the diversification of fodder production in North Kazakhstan and Akmola regions [6]. The Dauren is the first triticale variety registered in the register of breeding achievements in the North Kazakhstan and Akmola regions, created as a result of breeding work in the region [7]. However, at the moment there remains the problem of optimal agricultural technology of this crop in the region. The seeding rate, the variety, and their interaction with moisture availability are important factors affecting biomass production, grain yield, and feed quality of triticale, and usually, the method of studying the structure of the crop was used to discuss these effects [8]. The period of development of annual crops from germination through flowering to maturation determines the time and duration of critical periods for growth, which can seriously affect the quantity and quality of yields [9]. In the conditions of Northern Kazakhstan, where moisture is the determining factor of yield, the timing of sowing of grain crops should be calculated so that the period of maximum moisture demand (stem elongation-earing) falls at the end of the month of June-July, when the bulk of summer precipitation falls [10].

Choosing the right sowing dates allows maximising the results of the interaction of the genotype with the environment and thereby increasing the yield and baking qualities of wheat grain [11]. According to the researchers of the Irkutsk Research Institute of Agricultural Sciences, when cultivating new varieties of grain crops, a clear dependence of their productivity, grain quality, and economic efficiency indicators on seeding rates and sowing dates has been established. With an increase in the seeding rate, the number of productive stems increases, but the productive tilling capacity of plants and the weight of 1000 grains decreases [12].

The purpose of the study is to substantiate the optimal sowing dates and seeding rates of spring triticale in the zone of ordinary chernozems of Northern Kazakhstan, providing a maximum yield of grain products.

2. MATERIALS AND METHODS

The object of research were 2 new high-yielding varieties of spring triticale Dauren and Rossika of the mid-season maturation type. The originators of these varieties are the All-Russian Research Institute of Organic Fertilisers and Peat, the Vladimir Research Institute of Agriculture and S. Seifullin Kazakh Agrotechnical University.

The study was conducted in 2019-2021 at the pilot site of the North Kazakhstan Agricultural Experimental Station, located in the steppe zone of the Northern region, the climate is sharply continental, arid. The following methods were used in the study:

1. Phenological observations on the main phases of development – earing, maturation, and density of standing shoots. Methodology of state testing new varieties of agricultural crops, 2002.
2. Crop accounting was carried out by harvesting directly with the Sampo-130 combine harvester with the conversion of yield data to the standard 14% humidity and 100% purity of grain.
3. The structural analysis of the crop was carried out in the phase of the complete ripeness of grain. The following indicators were determined: plant height, ear grain content, grain weight per ear, the weight of 1000 grains, ear length, and productive tilling capacity. Methodological guidelines for the study of the world collection of the Institute of Plant Industry, 1977. Methods of national variety testing, 2010.
4. Mathematical processing of the obtained data was performed by the methods of dispersion and linear correlation [13].

Experimental data on the influence of sowing dates and seeding rates of spring triticale in the steppe zone of the Republic of Buryatia on yield show that the optimal seeding rates of spring triticale are in the range from 4 to 6 million pcs/ha. The optimal timing of sowing grain starts from May 15-20 and ends on May 25-30. The influence of these techniques on the change of the main elements of the structure of the spring triticale crop in the conditions of the steppe zone has also been investigated [14]. Different seeding rates of spring triticale seeds have a significant impact on both the elements of the crop structure and grain yield. The highest yield of spring triticale grain in recognised varieties is formed at an optimal seeding rate of 6 million germinating seeds per hectare. It was established that at high seeding rates (7 million germinating seeds per hectare) there is a significant decrease in all studied indicators compared to the control variant [15].

3. RESULTS

3.1 Features of meteorological indicators during the growing season of spring triticale

The years of research on meteorological indicators during the growing season were quite similar, with a slight deviation in 2019 (Figures 1-2). The amount of precipitation during the growing season in 2019 was 123.1 mm, with an average annual norm of 162.0 mm (76% of the norm). The average temperature for the summer months was in the range of 18.2°C, which is 0.4°C colder than normal. In May, a catastrophically severe drought was observed, the hydrothermal index (HI) was 0.33, but with good soil moisture reserves before sowing, this circumstance was not critical. In June, grain crops were optimally provided with moisture: HI – 1.21, long-term indicator – 0.79, which created the prerequisites for obtaining a good harvest. July 2019 was characterized by a catastrophically severe drought, HI – 0.35. The July maximum precipitation typical for the region did not appear in 2019. In August, there was a moderate drought, HI– 0.77, at the level of a long-term average indicator (Table 1).

The agrometeorological conditions of 2020 for the growth and development of spring triticale were characterized as arid, with early summer and August drought and pronounced July maximum precipitation. The hydrothermal index in May corresponded to a severe drought. In total, 133.1 mm of precipitation fell in the summer of 2020, which, with an average annual norm of 162.0 mm, amounted to 82% of the norm. The average temperature for the summer months was in the range of 19.2°C, which is 0.6°C warmer than normal. The prevailing dry weather conditions significantly accelerated the onset of waxy ripeness of grain crops, in general, and the growing season decreased by 10 days in comparison with long-term observations. The least amount of precipitation during the growing season was received in 2021, when there was also an early summer and August drought, with a pronounced July precipitation maximum. The HI in May was 0.18, in June – 0.43, which corresponds to a catastrophically severe drought, whereas in July – 1.12, or the satisfactory level. In total, 120.9 mm of precipitation fell during the summer (73% of the norm), at a temperature exceeding the norm by 0.9°C. In general, the years of observations were typical both in terms of moisture availability and temperature regime.

Table 1. Meteorological indicators of the growing season, 2019-2021

Year	Month	Precipitation, mm		Temperature, °C		HI
		Per month	Long-term annual average	Per month	Long-term annual average	
2019	June	56.8	44.0	15.6	18.6	1.21
	July	23.0	71.0	20.9	20.0	0.35
	August	43.3	47.0	18.1	17.2	0.77
	Over the summer	123.1	162.0	18.2	18.6	
2020	June	35.9	44.0	16.4	18.5	0.73
	July	75.6	71.0	21.4	20.0	1.14
	August	21.6	47.0	19.8	17.2	0.35
	Over the summer	133.1	162.0	19.2	18.6	
2021	June	22.0	44.0	17.2	18.5	0.43
	July	69.8	71.0	20.8	20.0	1.08
	August	29.1	50.0	20.4	17.2	0.46
	Over the summer	120.9	165.0	19.5	18.6	

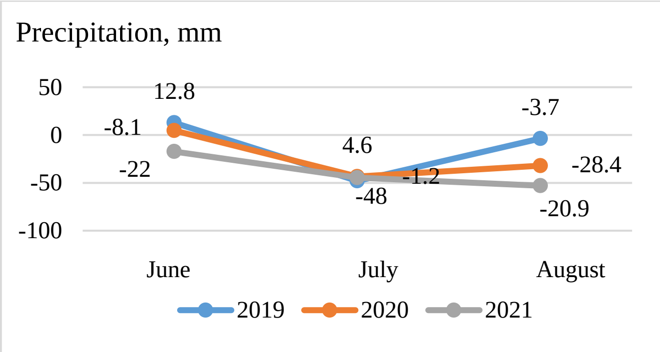

Figure 1. Deviation from the long-term annual average of precipitation during the growing season

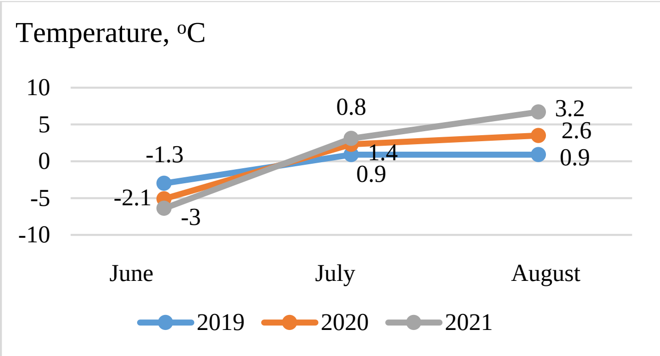

Figure 2. Deviation from the long-term annual average of temperature during the growing season

The sensitivity of plants to the ratio of day and night can vary slightly depending on the ambient temperature, humidity, intensity, and quality of lighting, as well as on mineral nutrition. Both the adult plant and the seed can react to the duration of illumination. With insufficient lighting, plants' assimilation and respiration intensity decrease, as a result of which the yield and seed quality decrease. The influence of biotic and abiotic factors on plants depends on moisture supply. When there is not enough moisture in the soil, plants lose turgor and drying occurs. Also, the amount of moisture in the soil will depend on the activity of soil microorganisms, which ensure the course of many extremely important processes (for example, the process of nitrification, or the decomposition of chemical compounds of active substances of pesticides).

3.2 The influence of sowing date and sowing rate on the yield of spring triticale

According to the results of a three-year study, it can be concluded that the optimal time for sowing spring triticale in the soil and climatic conditions of Northern Kazakhstan is shifting to a later sowing period, by the end of May (May 20-30). However, in the regions of mass distribution of triticale, the European part of Russia, Belarus, etc., early sowing dates are recommended. The postponement of sowing dates to later ones is based on climatic conditions and on the biology of culture in conditions under study. Thus, according to the results of phenological observations of the crop, it was noted that triticale plants are characterised by intensive development during the germination-earing period and the prolongation of vegetation during the earing-ripening period. Consequently, the period of maximum moisture demand (stem elongation-earing) by the time of crop development falls on 40-45 days. Combining the data obtained with the climatic conditions of the study period, it can be noted that only at the late sowing date (late May), the phases of stem elongation-earing fall on July, the period of annual summer precipitation maximums.

The main indicator of the correctness of the applied elements of technology is the final productivity of agricultural crops (Table 2). According to the experimental data obtained, the yield of spring triticale varieties increases from early to later. Thus, in the Dauren triticale, the yield for sowing on May 30 is 29.9 c/ha, which is 16% higher than earlier dates. According to the Rossika variety, the increase in the harvest of a later date is within 30% of the early one.

Table 2. Yield of spring triticale varieties depending on the sowing period and seeding rate, average 2019-2021

Variety	Sowing period	Seeding rate, million germinable seeds/ha	Yield, c/ha
Dauren	May 10	3.0	24.7
		4.0	26.5
		5.0	23.9
		6.0	24.7
		average by term	25.0
	May 20	3.0	25.7
		4.0	29.6
		5.0	24.8
		6.0	23.8
		average by term	26.0
	May 30	3.0	29.1
		4.0	33.0
		5.0	31.1
		6.0	26.5
		average by term	29.9
	LSD$_{0.5}$ (factor A) – sowing period		1.7
	LSD$_{0.5}$ (factor B) – seeding rate		1.8
	LSD$_{0.5}$ (factor AB) – interaction of factors		5.4
Rossika	May 10	3.0	21.6
		4.0	24.8
		5.0	25.1
		6.0	22.6
		average by term	23.5
	May 20	3.0	25.2
		4.0	27.5
		5.0	22.2
		6.0	24.9
		average by term	25.0
	May 30	3.0	28.9
		4.0	35.1
		5.0	34.1
		6.0	31.4
		average by term	32.4
	LSD$_{0.5}$ (factor A) – sowing period		1.6
	LSD$_{0.5}$ (factor B) – seeding rate		1.9
	LSD$_{0.5}$ (factor AB) – interaction of factors		5.4

According to the results of the variance analysis of the data, depending on the studied varieties, a significant difference was obtained. Thus, the effect of factor A (sowing period) provides the least significant difference in the Dauren variety – 1.7 c/ha, the Rossika variety – 1.6 c/ ha. The effect of factor B (seeding rate): the Dauren variety – 1.8 c/ha, Rossika – 1.9 c/ha. The indicator of residual dispersion (errors of experience) is quite low, 3.3 – for the Rossika variety, and 5.8 – for the Dauren variety. This indicates the statistical reliability of the experimental data obtained. The indicator for assessing the materiality of particular differences between factors, with the LSD$_{0.5}$ – 5.4 c/ha for both varieties, which is also a reliable indicator of the interaction of factors.

The fitting method was to find a group of curves that would describe the initial information with sufficient accuracy. According to Figure 3, the regularity of the yield growth of triticale Dauren is visible depending on the sowing period, considering the average deviations in the context of seeding rates.

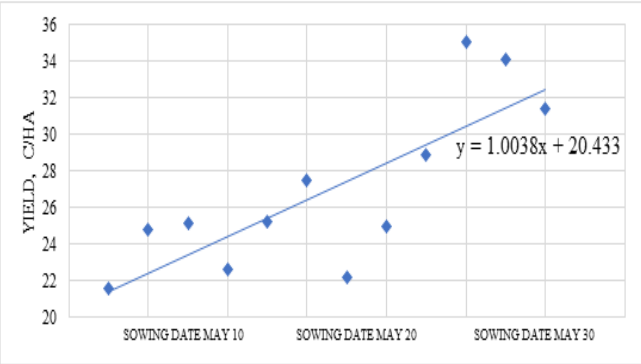

Figure 3. Average median yield of Dauren spring triticale, depending on the sowing period

The same pattern was noted for the Rossika triticale variety, a stable increase in average yields, regardless of seeding rate, towards a later sowing date. However, the slope of the straight median is much higher in the Rossika variety – 1.0038, which indicates a higher variation of the data, and a higher difference between the studied variants (Figure 4).

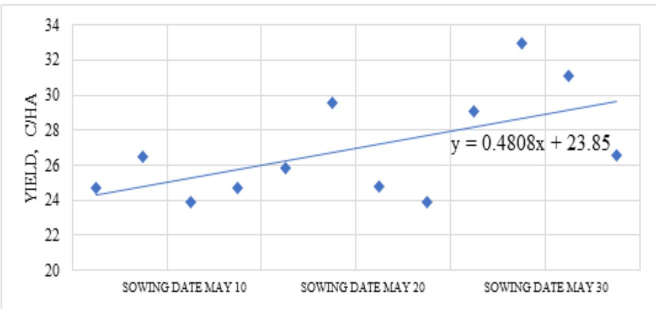

Figure 4. Average median yield of Rossika spring triticale, depending on the sowing period

It is known that the optimal density of the productive stem must be formed either by increasing the density of standing crops or by increasing the intensity of tillering [16-19]. Since spring triticale has a lower productive tilling capacity compared to other spring grains, it can be assumed that this crop reacts more than others to the optimisation of seeding rates [20-22]. Especially in the soil and climatic conditions of the north of Kazakhstan, where the determining factor in optimising seeding rates is the availability of moisture and nutrients. Therefore, for specific conditions of crop growth, an urgent problem is the study of seeding rates that are optimal for the studied zone, to form the maximum yield of triticale grain, considering varietal characteristics [23].

According to the data obtained, the studied varieties respond differently to changes in the seeding rate. The maximum yield for the Dauren variety (29.7 c/ha) was observed at a seeding rate of 4.0 million germinable seeds per ha, in the Rossika variety (27.1-29.1 c/ha) 4.0-5.0 million germinable seeds per ha. Sowing seeds with norms of 3.0-3.5 million, applicable for cereals common in the region (spring wheat, barley), and an increase in the seeding rate to 5-6 million germinable seeds per hectare, leads to a decrease in yield.

The error of approximation was used to compare the accuracy of the predictions. The forecast error depended on the length of the retrospective and the forecasting horizon. The optimal ratio between them was considered to be 3:1. According to Figure 5 and 6, the approximation error (R^2), at 3 degrees, is close to 1 in both cases, this indicates a minimal error and high reliability of the forecast. The difference in yield, depending on the seeding rate, for the Dauren variety is 3.2 c/ha or 11%, compared with the minimum seeding rate (3.0) with the optimal (4.0), and 4.7 c/ha or 16%, compared with the maximum seeding rate (6.0). In the Rossika variety, the yield shortfall in relation to the minimum seeding rate was 3.9 c/ha (13.4%), to the maximum – 2.8 c/ha (10%).

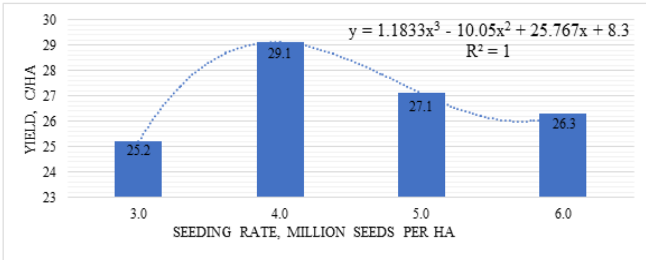

Figure 5. Average median yield of Dauren spring triticale depending on the seeding rate (data for 3 years)

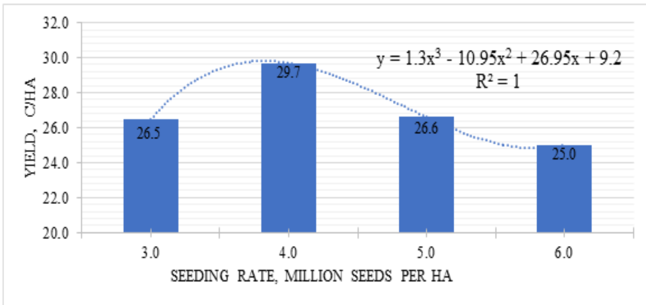

Figure 6. Average median yield of Rossika spring triticale depending on the seeding rate (data for 3 years)

Correlation assessment between the indicators of the structure and grain yield of spring triticale according to the experiment variants. By means of correlation analysis, the aim was to identify the dependence of the yield according to the variants of the experiment on the parameters of independent variables, in this case, indicators of the structure of the crop. According to the results of the analysis, a high correlation dependence of the following indicators of the crop structure on the seeding rate was revealed: the height of the plant at the level of 0.65-0.66 according to triticale varieties, which corresponds to a noticeable degree (on the Cheddock scale), the weight of the sheaf – 0.66-0.73 – noticeable and high degree, seed weight from 1 m^2 – 0.70-0.74 – high degree of correlation. At the same time, the indicators of the number and weight of seeds in the ear, productive tilling capacity, and the weight of 1,000 seeds did not have a close correlation with the seeding rate.

The sowing period provided a greater closeness of correlations with the indicators of the crop structure. So, the strength of correlations with the height of the plant corresponded to 0.9-1.0 – a very high degree. The sowing period factor had a high correlation on the indicators of the number and weight of seeds from the ear in the Rossika variety – 0.6-0.7 (significant and high degree), in the Dauren variety the correlation for this factor is significantly lower – 0.2-0.4 (weak and moderate degree). At the same time, the Dauren variety was more correlated in terms of productive tilling capacity – 0.9 (very high), compared with 0.5 (moderate) in the Rossika variety. To the same extent, the timing of sowing triticale varieties affected the weight of the sheaf and the weight of seeds from the sheaf (from $1m^2$). The degree of impact on the sheaf weight index ranged from 0.9-1.0, on the sheaf seed weight index – 0.85-0.88 (high degree). The analysis shows a weak correlation between the sowing period and the weight of 1000 grains.

4. CONCLUSIONS

According to the results of the experiment, it was revealed that the optimal sowing period for spring triticale varieties in the zone of ordinary chernozems of Northern Kazakhstan is the period of the second ten days – the third ten days of May, the optimal seeding rate is in the range of 4.0-5.0 million germinable seeds per hectare. These facts are confirmed by phenological studies in connection with the weather and climatic conditions of the area, productivity according to the experiment variants, and elements of the crop structure. Mathematical processing of the relationship of yield according to the experiment variants with the indicators of the crop structure reveals a high positive correlation of vegetative indicators of the plant, tilling capacity, and productivity from the optimal arming technique of triticale cultivation.

As a result of the analysis of the impact of each factor (sowing period, seeding rate) on the structure indicators, a positive effect of the optimal seeding rate on the height of triticale plants and signs of productivity – the weight of plants in a sheaf, the weight of seeds from 1m2 was noted. The optimal sowing period affects the vegetative indicators of plants (height, number and weight of seeds in the ear), productive tilling capacity, and productivity indicators (sheaf weight, sheaf grain weight). Prospects for future research are to investigate the statistics of the temperature difference in the morning and in the evening, as it has a great impact on the starch deposition in crops of spring triticale.

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