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SPRING WHEAT AND SPRING RAPESEED PRODUCTIVITY POTENTIAL

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SUMMARY

The best crop production technology depends on the approved scientific approaches and agricultural practices. Studying the elements of crop production technology is necessary to obtain stable and high-quality yields. The result's reliability reached validity from three years of field and laboratory studies conducted under typical conditions per modern methods and state standards. For the presented research, the spring wheat cultivated as the first crop of different fallow types began during 2020–2022 at the Kursabaev Farm, North Kazakhstan. The spring rapeseed cultivars and hybrids, planted on bare fallow soil, had various seeding rates in 2019–2021 at the Yessil Yessil State Grain Feed Variety Testing site in North Kazakhstan. The study showed that for 2020–2022, the highest spring wheat grain yield resulted in the variant with chemical fallow treatment. The highest grain yield in rapeseed surfaced from the bare fallow soil with cultivar 'Maikudyk' and the hybrid 'Builder,' with a seeding rate of 2.0 million seeds per hectare. The results revealed that fallow preceding a crop contributes to a better spring wheat harvest. Thus, this work allows for determining the most effective ways to increase crop yields under climate change and variations in other environmental factors.

Keywords: Spring wheat, spring rapeseed, seeding rate, chemical fallow, bare fallow, grain yield

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Key findings: As part of the study, in the conditions of the Zhambyl District of the North Kazakhstan Region in 2020–2022, the highest spring wheat yield occurred using chemical fallow treatment preceding a crop, with tillage of 16–18 cm. Treatment with bare and sown fallow showed lower efficiency with a difference of 0.19–0.42 t/ha. The highest spring rapeseed yield in the Esil District of the North Kazakhstan Region in 2019–2021 appeared at the seeding rate of 2.0 million germinating seeds per hectare in cultivar Maikudyk, while the increased seeding rate showed a decline in crop yield in 2019–2021.

INTRODUCTION

In the North Kazakhstan Region, agriculture plays an influential role in the local economy, with a significant focus on cereal crop cultivation, such as spring wheat and spring rapeseed (Ansabayeva, 2023; Ansabayeva and Akhmetova, 2024). The region is distinctly continental in climate with fertile soils, which offers ideal conditions for these crops (Madenova *et al*., 2023; Chebyshev *et al*., 2024; Kunanbayev *et al.,* 2024). However, the changing climate patterns and evolving agricultural market demands necessitate continuous improvements in cultivation techniques to sustain and enhance grain yield with better quality (Atabayeva *et al*., 2018; Shayaкhmetova *et al.,* 2023).

Global emphasis on sustainability increases with an imperative need to improve agricultural practices to ensure them further environment-friendly and economically viable in maize (Akhtariev *et al*., 2021) and spring wheat and rapeseed (Cherkasova and Rzaeva, 2019, 2021). Against this backdrop, the presented research explores innovative cultivation technologies to optimize grain yield and quality in response to these challenges due to changing climatic conditions.

The study of different elements of crop production technology is the foundation for obtaining high-quality yields of crops, and improved technology will enhance production efficiency (Ramazanova *et al*., 2021). Spring wheat has long occupied a leading position for acreage (Dosmanbetov *et al*., 2020), and recently, interest in spring rapeseed has surfaced due to breeders' achievements. Its use benefitted the food industry, increasing the demand for the said crop. In field crop production technology, selecting the preceding crop, crop cultivars, and hybrids is vital to fulfill all requirements (Fisunov and Rzaeva, 2021; Nasiyev and Dukeyeva, 2023).

Crop rotation is one of the essential tools to employ to enhance crop productivity considerably (Koryukina, 2020; Miller and Rzaeva, 2020b; Kochorov *et al*., 2023), carrying out basic tillage practices, with the preceding crop as vital in getting optimum grain yield in leguminous crops (Kiseleva and Rzaeva, 2021a, b; Rzaeva, 2021a, b). Paying particular attention to the seeding rate of spring wheat and rapeseed crops is a must (Cherkasova and Rzaeva, 2019, 2021).

Fallow tillage is the most relevant agrotechnical event (Miller and Rzaeva, 2020a), with the best results achieved by applying basic tillage in various field crops (Kiseleva and Rzaeva, 2021b; Rzaeva, 2021b; Asadulagi *et al*., 2024). The main criterion for evaluating numerous variants in the cropping system is the grain yield value (Suchshikh *et al*., 2023). The wheat yield grown after the fallow was higher (Utelbayev *et al.*, 2021), whereas its remoteness reduces this indicator in spring wheat (Ershov and Rzaeva, 2019; Rzaeva, 2021a, b). Studies showed that fallow preceding a crop contributes to a greater harvest of spring wheat grain than other preceding crops (Zabolotskikh *et al*., 2019). The promising study evaluated fallow types' effect on spring wheat yields and the influence of seeding rate on spring rapeseed cultivars and hybrids' grain yields.

MATERIALS AND METHODS

Field studies in the spring wheat cultivation by fallow types commenced in production conditions of the Kursabaev Farm, Muromskoye Village, Zhambyl District, in North Kazakhstan Region in 2020–2022. Ground research on the effect of seeding rate on the yield of varieties and hybrids of spring rapeseed in North Kazakhstan transpired from 2019 to 2021 at the Yessil State Grain Feed Variety Testing site in the village of Yavlenka, Yessil District, North Kazakhstan Region. The spring wheat cultivation used the 'Uralosibirskaya' variety with a seeding rate of 5.5 million germinating seeds ha^{-1}. The study on seeding rate influence on grain yield of spring rapeseed progressed with relative comparison to five cultivars (Yubileinyi - standard, Geros, Maikudyk, Hunter, and Makhaon) and three hybrids (Kalibr, Builder, and GEN0009) (Cherkasova and Rzaeva, 2019).

Research on spring wheat cultivation proceeded in crop rotation according to the following experiment variants: a) Fallow (bare, sown, and chemical), b) spring wheat, c) spring wheat, and d) spring wheat (Table 1). In spring wheat, the area under each fallow field was 1.0 ha with three-fold repetitions (using 3.0 ha for the experiment). The area under spring wheat crops equaled 3.0 ha (one hectare after each fallow type). In the spring wheat crop (the second field of crop rotation), the experiment used a tank mixture of herbicides Ovsyugen Extra (0.6 l/ha) + Phenizan (0.2 l/ha). Spring wheat sowing continued with the SZS-2.1 spray, made with an Avagro sprayer, with wheat harvesting employing an Esil 740 combine harvester. Wheat yield data recording included recalculation for 100% purity and 14% grain moisture.

The study of rapeseed cultivars and hybrids proceeded according to several seeding standards, i.e., 2, 2.5, and 3 million germinating seeds per hectare (Koryukina, 2020). The area of the accounting plot was 25 m^2, with fourfold repetitions with two tiers in the rapeseed experiment on the bare fallow soil (Dospekhov, 1979).

Data recorded and analysis

Soil and agronomic data comprising soil moisture content, nitrogen levels, and agronomic parameters, such as plant height and biomass, received periodic recording during the growing season to monitor the impact of different fallow variants. After harvesting the grain yield (t/ha), recorded data of spring wheat and rapeseed started across different fallow treatments, i.e., bare (control), sown (Sudan grass), and chemical fallow. All the data underwent an analysis of variance, with the least significant difference ($LSD_{0.05}$) test used to determine the significance and differences among the variant means for various traits in spring wheat and rapeseed grown under different fallow conditions across years.

Table 1. Experimental variants used in the three years of study.

Variants	Conditions	Time of the experiment	Experiment
Bare (black) fallow	when weeds appear	June 11-20, July 21-31 August 11-20	tillage with KPSh-9 at 10-12 cm tillage with KPSh-9 at 16-18 cm
Sown fallow (Sudan grass)	after Sudan grass sowing	May 1-31 July 11-20 July 11-20 August 11-20	rolling with 3KSH-6 Sudan grass harvesting for green feed tillage with KPSh-9 at 10-12 cm tillage with KPSh-9 at 16-18 cm
Chemical fallow	when weeds grow to a height of 15 cm	Two treatments with a difference per month: June 21-30, July 20-31	application of herbicides to a height of 15 cm (glyphosate-containing Sprut Extra 54% at a dosage of 2.5 l/ha + Dicamba 48% at a dosage of 0.1 l/ha)

Table 2. Grain yield of spring wheat cultivated on different fallow types.

Fallow	Years				Compared to bare fallow (control), 2020–2022	
	2020	2021	2022	2020–2022	t/ha	%
Bare (control)	1.80	2.06	2.42	2.10	-	100
Sown (Sudan grass)	1.75	2.01	1.84	1.87	-0.23	-11.00
Chemical	1.70	2.40	2.76	2.29	+ 0,19	+9.04
$LSD_{0.05}$	0.08	0.07	0.11	-	-	

RESULTS AND DISCUSSION

Based on the 2020 study results, the grain yield of spring wheat grown after the fallow types ranged from 1.70 to 1.80 t/ha (Table 2). For bare fallow, the grain yield was higher by 0.05 t/ha than the sown fallow and by 0.10 t/ha than chemical fallow. The difference between the sown and chemical fallow was 0.05 t/ha in spring wheat (Abdriisov and Rzaeva, 2022). In 2021, the highest spring wheat grain yield (2.40 t/ha) was apparent for the variant of chemical fallow, which exceeded the control variant (bare fallow) by 0.34 t/ha and sown after fallow by 0.39 t/ha. This significant increase in spring wheat grain yield underscores the effectiveness of chemical fallow in enhancing soil fertility and water retention, thereby boosting crop productivity.

Compared to the control variant, the wheat grain yield for the sown fallow was 0.05 t/ha less, while the yield for the chemical fallow was 0.34 t/ha more. Notably, a significant yield difference of 0.39 t/ha between the sown and chemical fallow treatments occurred, indicating an advantage favoring chemical fallow for enhancing spring wheat productivity (Abdriisov and Rzaeva, 2022).

In the control variant (bare fallow), the spring wheat yield in 2022 was 2.42 t/ha, whereas, for sown fallow, the grain yield was less than the control variant by 0.58 t/ha. For chemical fallow, the grain yield was more than the control variant by 0.34 t/ha with a minimum difference of 0.11 t/ha. However, the difference in grain yield of spring wheat between the sown and chemical fallow was 0.92 t/ha.

On average, over the three years of research (2020–2022), the spring wheat grain yield for bare fallow was 2.10 t/ha, and in sown fallow, the yield was 0.23 t/ha (11.0% lower than the control). However, the grain yield for chemical fallow was 0.19 t/ha (9.04% higher than the control). The difference between the sown and chemical fallow was 0.42 t/ha. This consistent disparity highlights the efficacy of chemical fallow in promoting higher yield than the traditional sown fallow. These results suggested that integrating chemical fallow into crop rotation strategies could be a primary approach for enhancing wheat production in the same agro-climatic conditions. According to the results of 2020–2022, the chemical fallow variant was distinct with a higher grain yield of spring wheat (2.29 t/ha), which exceeds the variants with bare and sown fallows by 0.19–0.42 t/ha (Abdriisov and Rzaeva, 2022).

Based on the variants used during 2020, studies on chemical fallow using tillage in the fallow field have shown that the spring wheat grain yield ranges from 1.70 to 1.88 t/ha (Table 3). The highest grain yield (equal to 1.88 t/ha) was evident in the variant using tillage at 16–18 cm on chemical fallow, which exceeds the control variant (without tillage) by 0.88 t/ha. The difference between the variants by tillage depth was 0.06 t/ha in favor of the tillage at 16–18 cm compared to tillage at 10–12 cm. In 2021, the maximum spring wheat grain yield (2.60 t/ha) was similar to the previous year, obtained with chemical fallow using tillage at 16–18 cm on the 20th of August. However, it exceeds the control variant by 0.20 t/ha and the variant with tillage at 10–12 cm by 0.07 t/ha.

Table 3. Grain yield of spring wheat cultivated on combined fallow (chemical fallow + tillage).

Chemical fallow	Tillage with KPSh-9, 20 of August	2020	2021	2022	Average for 2020–2022 (t/ha)
Sprut Extra 54% (2.5 l/ha) + Dicamba 48% (0.1 l/ha) with two treatments (21 to 30 of June, af30 of July)	no tillage (control)	1.70	2.40	2.76	2.29
	16-18 cm	1.88	2.60	2.85	2.44
	10-12 cm	1.82	2.53	2.80	2.38
$LSD_{0.05}$		0.06	0.07	0.04	-

Overall, the crop season 2022 was distinguishable with the highest grain yield in the studied years, and in all variants, the grain yield ranged from 2.76–2.85 t/ha in spring wheat. However, the maximum grain yield (2.85 t/ha), as in the previous two years, resulted in the chemical fallow variant with tillage at 16–18 cm, which also exceeded the control variant by 0.09 t/ha and the tillage variant at 10–12 cm by 0.05 t/ha. The average grain yield of spring wheat over the three years of research (2020–2022) was 2.29 t/ha on chemical fallow with no tillage in August. The use of tillage at 10–12 cm in that month allowed for an increase of 0.09 t/ha in the spring wheat grain yield, and an increase in the tillage variant at 16–18 cm was 0.15 t/ha. The difference between both tillage variants was 0.06 t/ha.

Thus, according to the study in 2020–2022, the considerable higher grain yield in spring wheat (2.29 t/ha) resulted in the variant with chemical fallow (Sprut Extra 54% [2.5 l/ha] + Dicamba 48% [0.1 l/ha] with two treatments, i.e., on the 20th to 30th of June and the 30th of July) compared with bare and sown fallows. However, the excess was 0.19–0.42 t/ha versus the bare and sown fallows. The positive effect of tillage at 16–18 cm using chemical fallow was prominent.

Cultivating rapeseed on bare fallow garnered the highest productivity from the variant, with a seeding rate of 2.0 million germinating seeds. These findings were consistent with past research, which reported that lower seeding rates usually enhance individual plant performance and reduce intraspecific competition, leading to higher overall productivity in oilseed crops (Makenova *et al*., 2023). The latest results also got support from the meta-analysis by MacLaren *et al*. (2023), who highlighted that seeding rates of around 2.0 million seeds per hectare were often optimal for balancing plant density and maximizing resource use efficiency in rapeseed, particularly in environments with limited water resources like those typically found in bare fallow conditions.

An increased seeding rate reduces the grain yield; however, the best indicator in the three years of research emerged in the wheat cultivar ‘Maikudyk,’ with a seeding rate of 2.0 million germinating seeds. However, with an increase in the seeding rate, its average grain yield for three years decreased from 3.52 to 3.20 t/ha. Among the rapeseed hybrids, the hybrid ‘Builder’ was notable with a grain yield of 3.24 t/ha, which also exceeded the rapeseed standard cultivar ‘Yubileinyi’ by 0.15 t/ha, with a seeding rate of 2.0 million germinating seeds (Table 4).

Furthermore, past research underlined the importance of selecting hybrids based on data from comprehensive regional trials, reporting varied hybrid performances in field crops across different climatic zones (Konate *et al*., 2023; Ye *et al*., 2023). The success of cultivar 'Builder' in recent trials encourages further localized testing to confirm its adaptability and optimize cultivation practices under different environments. It reinforces the idea from this research that selecting and promoting specific rapeseed hybrids, such as 'Builder,' requires a deep understanding of their ecological and agronomic responses to specific cultivation conditions.

Table 4. Grain yield of spring rapeseed cultivars and hybrids based on the seeding rate, with bare fallow as the preceding crop.

Cropping seasons	Seeding rate, germinating seeds per hectare	Cultivars / hybrids								
		Yubileinyi (standard)	Geros	Maikudyk	Hunter	Makhaon	Kalibr	Builder	GEN0009	LSD_{05}
2019	2 (control)	2.17	1.98	2.84	1.87	1.82	2.41	2.13	1.98	0.28
	2.5	2.51	2.61	2.66	2.48	2.30	2.18	2.06	2.34	0.35
	3	2.08	1.77	2.59	2.06	1.81	1.87	1.73	1.91	0.32
2020	2 (control)	4.02	3.81	4.20	3.43	3.43	3.51	4.28	3.42	0.26
	2.5	3.80	3.70	4.01	3.31	3.32	3.31	4.17	3.23	0.12
	3	3.60	3.50	3.81	3.11	3.15	3.02	3.82	3.01	0.14
2021	2 (control)	3.09	2.88	3.52	2.65	2.63	2.96	3.21	2.70	0.29
	2.5	3.16	3.16	3.34	2.89	2.81	2.75	3.12	2.79	0.21
	3	2.84	2.64	3.20	2.59	2.48	2.45	2.78	2.46	0.18
Average for 2019–2021	2 (control)	3.09	2.89	3.52	2.65	2.63	2.96	3.24	3.21	0.28
	2.5	3.16	3.16	3.34	2.89	2.81	2.75	3.12	2.79	0.22
	3	2.84	2.64	3.20	2.59	2.48	2.45	2.78	2.46	0.24
Deviation from the standard (t/ha)	2	–	-0.2	0.43	-0.44	-0.46	-0.13	0.15	0.12	
	2.5	–	0	0.18	-0.27	-0.35	-0.41	-0.04	-0.37	
	3	–	-0.2	0.36	-0.25	-0.36	-0.39	-0.06	-0.38	

Over the years of the study (2019–2021), the highest average grain yield was evident in the spring rapeseed cultivar 'Maikudyk' (3.52 t/ha) by cultivating on bare fallow at the rate of 2.0 million germinating seeds, with an excess of 0.43 t/ha over the standard cultivar. However, the increased seeding rate leads to a decreased rapeseed yield.

CONCLUSIONS

The results confirmed the importance of optimal preceding crop and tillage methods to achieve a maximum crop yield. The chemical fallow with tillage (16–18 cm) has proven the most effective option in spring wheat production. In spring rapeseed, the seeding rate also plays an influential role in optimizing grain yield, and the cultivar 'Maikudyk′ and hybrid 'Builder' showed the best results by cultivating on bare fallow. Thus, the research achieved the goals of the study to evaluate and identify optimal factors for cultivating spring crops in climatic conditions of the North Kazakhstan Region. The results provided valuable information for agricultural enterprises and experts who can use this data to optimize crop cultivation technology and increase yields further.

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