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RESEARCH ARTICLE

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Efficiency of Cultivation of Spring Triticale in Traditional and Organic Farming in the Arid Climate of Northern Kazakhstan

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ABSTRACT

The gradual progression of climate change towards arid conditions is resulting in a widespread reduction in the yield of the predominant crop, namely wheat. Kazakhstan, as the largest agricultural nation in Central Asia, relies heavily on rain-fed cultivation, with 93% of its arable land under this practice. This study explores the feasibility of growing spring triticale, as an alternative to spring wheat, in the dryland regions of northern Kazakhstan. Over the period of 2018-2022, spring triticale was cultivated using both conventional and organic farming methods, employing various combinations of mineral and organic fertilizers. The yield of triticale was notably impacted by the prevailing weather conditions during the growth cycle. Optimal grain yields were achieved through both conventional and organic farming practices, particularly following fallow periods. These fallow periods not only resulted in higher yields but also maximized profitability. The suggested fertilizer strategies offer farmers a reliable means to consistently attain lucrative returns when cultivating triticale, irrespective of climatic variations.

Keywords: Agricultural practices; Crop yield; Mineral fertilizer; Organic farming; Triticale

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INTRODUCTION

Climate change has raised concerns among scientists and farmers regarding the stability of agricultural production (Suleimenova et al., 2021). Increasing aridization due to climate change is contributing to reduced productivity in terrestrial agroecosystems (Arora, 2019; Serekpayev et al., 2016; Zhao et al., 2017; Javadinejad et al., 2021). This problem is especially relevant for northern Kazakhstan, located in the zone of risky agriculture, characterized by harsh natural conditions (Schierhorn et al., 2020; Karatayev et al., 2022). This is expressed in a large amplitude of temperature fluctuations (both positive and negative), prolonged frosty and snow-free winter, low humidity, and low precipitation during the warm period, are the characteristics of the continental climate (Zabolotskikh et al., 2021). The annual amount of precipitation in northern Kazakhstan ranges from 250 to 400mm, with 2/3 of precipitation falling from April to October. The observed scarcity and unevenness of precipitation during the summer period is a serious abiotic stress for various crops grown in the region. Another feature is that in 50% of cases, the growing season is dry (World Bank, 2014; Serekpayev et al., 2016) and the moisture deficit can be more than 600mm (Zhao et al., 2017).

In addition to unstable yields, the pricing factor for final products is of great importance for farmers, which is closely related to the economic and political situation in global markets and has also not been stable recently. These factors lead to significant fluctuations in the price of grain crops. Therefore, the expansion of the range of crops adapted to arid conditions and capable of providing high profitability of final products is a promising field.

Given the aridity of the climate and the short growing season of 85-100 days, the set of crops cultivated in this region is limited, and more than 80% of the acreage is occupied with spring soft wheat. Most of the acreage (about 17.5 million ha) is used for non-irrigated agriculture (Karatayev et al., 2022). Today, climate change towards increased aridization threatens the crop production industry in the region (Schierhorn et al., 2020; Karatayev et al., 2022). Therefore, the expansion of the range of cultivated crops resistant to arid conditions is relevant. One of the promising crops for this region is spring triticale. This crop, being an interspecies hybrid of wheat

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and rye, adopts the best qualities from both parent crops, which makes it a valuable food and fodder crop. It is widespread in Europe and the Commonwealth of Independent States (CIS). Approximately 91% of all triticale produced in the world is grown in Europe, 3.4% in China, 3.5% in Oceania, 1.5% in America, and 0.1% in Africa (FAOSTAT, 2014). The advantage of this crop is its ability to accumulate more protein (14-18%) in grain under equal conditions with wheat (Pogonec, 2015). In comparison with wheat, it is more resistant to drought and high temperatures (Kirchev & Georgieva 2017; Dutbayev et al., 2023).

In northern Kazakhstan, traditional approaches to crop cultivation are used. The following basic elements are characteristic of traditional farming: soil treatment with flat-cutting tools, snow retention, application of phosphorus fertilizers, sowing of grain crops in the second half of May, and the use of various groups of pesticides and varieties of different ripeness groups. All these measures are aimed at intensification, obtaining the greatest profit and the maximum possible yield of cultivated crops.

Organic farming is developing in Kazakhstan, where the use of mineral fertilizers and synthetic pesticides is prohibited in crop cultivation (Le Campion et al., 2020; Yakovlev et al., 2024). Organic products are characterized by high purchase prices and extremely limited supply in this region. According to International Federation of Organic Agriculture Movements (IFOAM) statistics (2021), Kazakhstan in 2019 ranked third in Asian countries in terms of the area allocated for organic farming, which equaled 294,289 ha. In the future, the development of this field may reduce competition in the region by diversifying grain production.

One of the limiting factors affecting crop yields after moisture and temperature is nutrients. The most important of them is phosphorus, the natural content of which in the soils of northern Kazakhstan is extremely low. The problem of nitrogen nutrition of plants in the arid conditions of the region is not so critical and to a certain extent is solved by the presence of fallow land in crop rotation or by mechanical treatments in the spring or autumn periods. Potassium does not limit the yield of crops cultivated in the rain-fed conditions of northern Kazakhstan, since the soils of this region are rich in this element (Naliukhin et al., 2024).

In the context of traditional farming, the issues of mineral nutrition of cultivated crops are solved by the introduction of mineral fertilizers, the production of which is well established in Kazakhstan. In organic farming, plants are supplied with nutrients from products of animal or plant origin. There are very few certified organic livestock farms in Northern Kazakhstan that can supply manure as fertilizer. Therefore, cultivating perennial grasses as organic fertilizers (green manure or mulch) will make it easier for farmers to feed plants and increase soil fertility.

Besides the listed abiotic factors that affect crop productivity, biotic factors are no less important. Weed vegetation hurts the yield of cultivated plants, competing for moisture, nutrients, and space (Gallandt, 2014). In traditional farming, this problem is solved by the use of mechanical treatments (on fallow land, during the preparation of the winter, before sowing) and herbicidal treatments (during the crop growing season). In organic farming, weed control is carried out only by the use of mechanical treatments, since the use of herbicides is unacceptable. The study aimed to assess the yield and economic efficiency of organic and traditional methods of cultivation of spring triticale in the conditions of aridization of the climate in northern Kazakhstan.

MATERIALS & METHODS

Experimental Design

The study was carried out for five years, from 2018 to 2022 at the «Scientific-production center for grain farming named after A. I. Barayev» LLP (N51°36'44.47"; E71°02'40.27"). The soil of the site is southern carbonate low-humus chernozem of heavy granulometric composition. The humus content in the 0-20cm soil layer is 3.4%, gross nitrogen and phosphorus content is 0.22 and 0.12%, and carbonate content is about 5%. The actual acidity of the arable layer is slightly alkaline (pHH2O=7.3).

The object of the study is the Rossika variety of spring triticale, which was cultivated using the traditional and organic methods on fallow and stubble as preceding crops in a three-field crop rotation: fallow – triticale – triticale. The experiments were established in time and space, and the repetition of the treatments was four-fold. The fertilizer treatments are presented in Table 1. The size of the plot was 4.3x30m (129 m2). Triticale sowing was carried out on May 15, which is the optimal time for sowing grain crops in northern Kazakhstan (Nurgaziyev et al., 2024). The seeding rate was 2.2 million germinating seeds per 1 ha with embedding in the soil for 5-6cm. The growing season of spring triticale ranged from 90 to 100 days over the years of the study.

Table 1: Fertilizer treatments and the content of main nutrients in traditional and organic farming systems

Treatments	Dose	Number of active ingredients (kg/ha)		
		nitrogen	phosphorus	potassium
		Traditional farming		
1. Control: P40 on fallow land (background)	N9P40	9	40	0
2. Background+N20 in rows when sowing	N9P40+N20	29	40	0
3. Background+N40 in rows when sowing	N9P40+N40	49	40	0
4. Background+N60 in rows when sowing	N9P40+N60	69	40	0
5. Background+N80 in rows when sowing	N9P40+N80	89	40	0
		Organic farming		
1. Control: yellow melilot biomass	4.71t/ha	143	16	108
2. Sainfoin biomass	4.71t/ha	144	16	139
3. Alfalfa biomass	4.32t/ha	135	16	103
4. Awnless brome biomass	4.98t/ha	132	16	143
5. Wheatgrass biomass	4.85t/ha	117	16	115

Weeds were accounted for before sowing and before harvesting triticale by applying a 0.25 m2 frame. The weeds were selected from the entire area of the frame, their species were determined, and they were counted. After that, the raw aboveground mass was weighed, and after drying, the absolutely dry mass of weeds was weighed.

The fallow fields were established after harvesting the melilot for seeds. The preparation of the fallow field using the two methods was carried out in the same way according to the requirements of soil-protective agriculture (World Bank, 2014; Baibussenov et al., 2021). The first fallow treatment was started in the first decade of June with flat-cutting tools to a depth of 5-7cm. The next three tillages were carried out at an interval of 15-25 days, with a gradual deepening of the tools up to 16cm. The last 25-27cm treatment was carried out in late August and early September.

In traditional cultivation, mineral fertilizers were used. Ammophos (10-46-00) (40kg/ha of the active substance) was added to the reserve for two years in the fallow field with a horizontal screen to a depth of 12-16cm, under one of the treatments of the fallow field (Nasiyev & Dukeyeva, 2023; Yakovlev et al., 2024; Olzhabayeva et al., 2024). The introduction of various doses of ammonium nitrate (34-00-00) for fallow and stubble was carried out when sowing the seeds in rows. During the triticale growing season, we used a full range of synthetic pesticides. The seeds were treated with the Yunta preparation (imidacloprid, 233 g/l+tebuconazole, 13g/L) at a dose of 1.75l/t before sowing. In the tillering phase of triticale (BBCH code 25-29), the tank mixture of herbicides against dicotyledonous perennial and annual weeds called Aesthete (2.4-D, in the form of 2-ethylhexyl ether, 600 g/l) in the dose of 0.6 l/ha, Gallant (tribenuron-methyl 750g/kg) in the dose of 0.02kg/ha, and Trend 90 (surfactant) in the dose of 0.15L/ha. In the triticale tubulation phase (BBCH 30-35), the herbicide Puma super 100 (phenoxapropp-p-ethyl, 100 g/l + mephenpyr-diethyl (antidote), 27 g/l) in the dose of 0.6L/ha was used against monocotyledonous weeds. In the phase of stem elongation and ear formation (BBCH 37-51), a solution mix of Engio 247 (thiamethoxam 141 g/L+lambda-cygolothrin 106g/L) in the dose of 0.12l/ha+Rex Duo 49.7 (thiophanate-methyl 310g/L+epoxiconazole 187g/L) in the dose of 0.3L/ha was used to control the number of pests and reduce the spread of leaf-stem diseases.

In organic farming, crushed aboveground mass of perennial grasses was utilized as fertilizers, which are traditionally cultivated in northern Kazakhstan, such as yellow melilot (Melilótus officinalis), common sainfoin (Onobrychis viciifolia), alfalfa (Medicágo satíva), awnless brome (BrōMus inērmis), and wheatgrass (Agropýron). Perennial grasses were grown in a separate field. In the phase of maximum accumulation of nitrogen, phosphorus, and potassium in the aboveground biomass, they were mowed, dried, and introduced into the fallow field. For the yellow melilot, alfalfa, and sainfoin, this is the phase of the beginning of flowering, for the awnless brome, the phase of ear emergence, and for the wheatgrass the phase of earing. No pesticides were used in the organic method of cultivation.

Doses of organic fertilizers were calculated considering the provision of a deficiency-free balance of mobile phosphorus in the soil. The treatments of the experiment and the dose of fertilizers are presented in Table 1.

Sampling and Measurement

Productive moisture before sowing was determined in a meter layer of soil, every 10cm using the gravimetric method.

The content of N-NO3 in the soil layer 0-40cm before sowing was determined using the ionometric method. P2O5 content in the 0-20cm soil layer was determined using the Machigin method for carbonate soils, which is similar to the Olsen-P method (Steinfurth et al., 2021).

The triticale was harvested in the phase of full ripeness with the Wintersteiger Delta combine harvester, site by site, which was followed by weighing. The grain harvest from the plots was recalculated to standard humidity (14%) and purity (100%).

Weeds were accounted for before sowing and before harvesting triticale using a 0.25m^2 frame. The weeds were selected from the entire area of the frame, their species were determined, and their number was calculated. After that, the raw aboveground mass was weighed, and after drying, the dry mass of weeds was weighed.

The economic efficiency of the cultivation of spring triticale with traditional and organic cultivation methods was calculated using technological maps and the market value of resources and wages in 2022 prices. The direct costs included the costs of fertilizers, fuels, lubricants, pesticides, wear and tear, repair of machinery, seeds, worker wages, and certification and inspection in organic farming. Calculations were carried out according to the prevailing market rates in the remuneration system of the A.I. Barayev Scientific and Production Center of Grain Farming and the whole of northern Kazakhstan for 2023.

Climate

The weather during the growing season (June-August) of spring triticale from 2018 to 2022 was characterized by significant variability in the temperature regime and different amounts and unevenness of precipitation by month (Fig. 1). In 2018, the average daily temperature for three months of vegetation was 1.1°C below the average annual norm (17.4°C), the minimum values were noted in June and August and equaled 16.9 and 15.3°C. The amount of precipitation that fell during the same period was 1.5 times higher than the average annual practice (134.7mm), with a maximum in June (69.3mm) and August (85.5mm). In 2019, the air temperature for the entire growing season was close to the climatic norm (18.1°C), June was cooler by 4.2°C, and July and August exceeded the monthly average by 2.1 and 0.8°C. Precipitation at the level of the average annual data poured only in June (40.5mm), and in the following months, this indicator was 1.5 and 3.7 times lower than normal. In 2020, the temperature background of the growing season was 0.8°C below normal (17.7°C). June and July were cool (2.5 and 1.3°C below normal), and

August was the hottest month (2.3°C above normal). The precipitation during the growing season was 10% lower than the annual average, with the highest amount occurring in June. The development of triticale in 2021 took place under conditions of elevated temperature background and lack of precipitation. The average daily temperature in June and July 2022 was above normal by 1.9 and 1.2°C, and in August, it was at the level of the annual average. The amount of precipitation from June to August was below the long-term values.

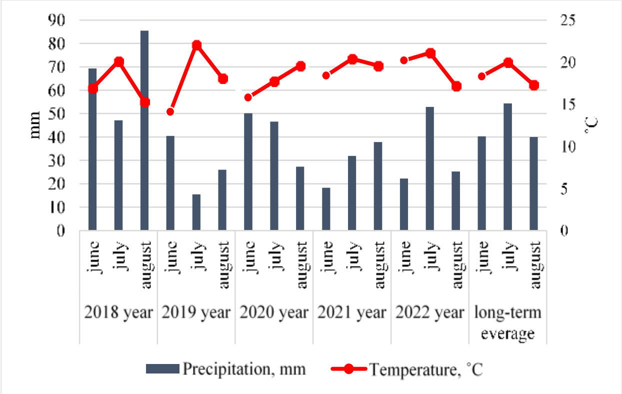

Fig. 1: Meteorological conditions during the study years (2018–2022) compared to the long-term average (1936–2022) at the Shortandy meteorological post.

Thus, favorable weather for the growth and development of spring triticale was observed only in 2018. The next four years of the study (2019-2022) were characterized by unfavorable weather. Negative changes in hydrothermal conditions towards aridity indicate an increase in climate desertification in the region.

Statistical Analysis

Statistical processing of the results was carried out using the methods of analysis of variance (ANOVA) with the least significant difference (LSD, p<0,005) in the SNEDECOR specialized software.

RESULTS & DISCUSSION

The Content of Productive Moisture and Nutrients in the Soil before Sowing Spring Triticale

The soil moisture content in a meter layer before sowing triticale in traditional and organic farming was the same level for both fallow and stubble (Fig. 2). Thus, after fallow, moisture reserves were assessed as satisfactory (118.6mm) and good (132.0-143.9mm), for stubble - as satisfactory (107-130mm).

The content of nitrate nitrogen before sowing triticale after fallow as a preceding crop in both organic and traditional farming in 2018 corresponded to an increased level and in 2019-2021 – to a high level (Table 2). A similar situation was observed in stubble fields; there were no differences between the farming systems. Thus, in 2019, the content of N-NO3 was at the average level, in 2020-2021, it was increased, and in 2022, it was high (Kurishbayev et al., 2020).

As in the case of nitrogen, the farming system did not affect the amount of mobile phosphorus in the soil before sowing triticale. The P2O5 content varied according to the study years and preceding crops from average (23-28mg/kg) to increased (31-35mg/kg).

Table 2: Oil content of nitrate nitrogen (N-NO_3) and phosphorus (P_2O_5) before sowing spring triticale in different farming systems, mg/kg of soil.

Year	N-NO_3		P_2O_5	
	Traditional farming	Organic farming	Traditional farming	Organic farming
Triticale after fallow				
2018	11±1.2	11±1.0	35±2.6	35±2.0
2019	24±2.1	36±2.8	31±2.0	27±1.5
2020	28±2.3	22±2.0	34±2.1	35±2.8
2021	23±2.1	27±2.5	37±2.0	26±2.0
Triticale after stubble				
2019	10±1.0	9±1.0	32±2.1	32±2.0
2020	17±1.5	19±1.7	28±2.0	28±1.8
2021	16±1.2	12±1.3	24±1.9	28±2.0
2022	17±1.7	22±2.2	25±1.3	23±2.9

± standard deviation

Quantitative and Weight Accounting of Weeds before Sowing and Harvesting Triticale

The assessment of the weed infestation in the experiments showed that before sowing triticale in both traditional and organic farming, the treatments of the experiment were weed-free in all study years.

Recording the number of weeds before harvesting triticale allowed us to establish a reliable difference between traditional and organic farming based on two preceding crops (fallow, stubble). The least weed infestation of triticale crops in the autumn period was noted in traditional farming (Fig. 3), where the number of weeds after fallow varied from 4.6 to 11.4pcs/m^2 over the years, while with organic farming this number was from 12.3 to 24.0pcs/m^2.

The species composition of weeds in traditional and organic farming was represented by the same species. Of the annual weeds, the most widespread were red-root amaranth (*Amaranthus retrofléxus*), goosefoot (*Chenopódium álbum*), proso millet (*Panicum miliaceum*), common wild oat (*Avena fatua*), and yellow foxtail (*Setaria pumila*). The species composition of perennial weeds was represented by field bindweed (*Convolvulus arvēnsis*) and sometimes creeping thistle (*Cirsium arvense*).

The dry mass of weeds in organic farming was significantly higher than in traditional farming both in fallow and stubble treatments (Fig. 4). Thus, in traditional farming, the dry mass of weeds, depending on the year, varied from 5.0 to 15.0g/m^2, and on organic backgrounds, their mass was 1.5-6 times greater, which was confirmed by statistical processing.

Triticale Grain Harvest

The yield of spring triticale in the study years varied widely, both by preceding crops and by farming systems. During the five-year observation period, the yield of triticale in organic farming was always significantly lower than in traditional farming (Table 3). The decrease in the yield of triticale in organic farming (compared to traditional farming), depending on the year, ranged from 38 to 42% for fallow and from 41 to 59% for stubble.

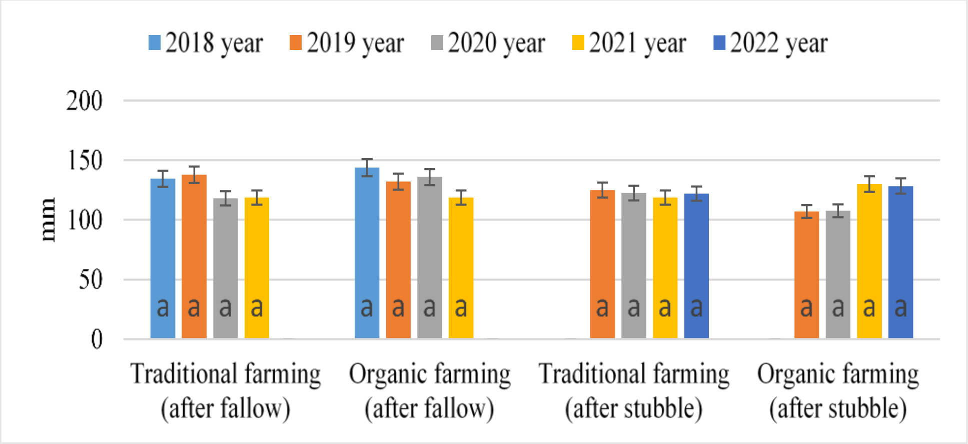

Fig. 2: Productive soil moisture content in a meter layer before sowing spring triticale for traditional and organic farming systems. *Statistical significance at P<0.05.

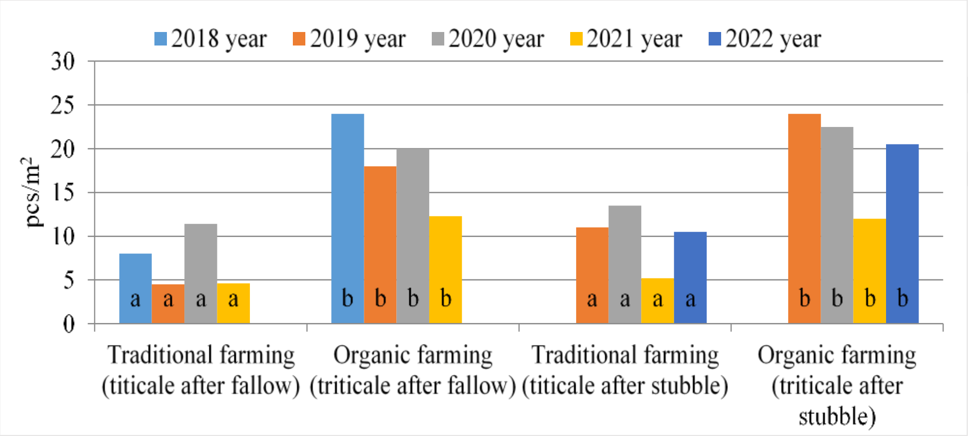

Fig. 3: Number of weeds before harvesting spring triticale depending on the farming system and preceding crop (fallow and stubble). *Statistical significance at P<0.05.

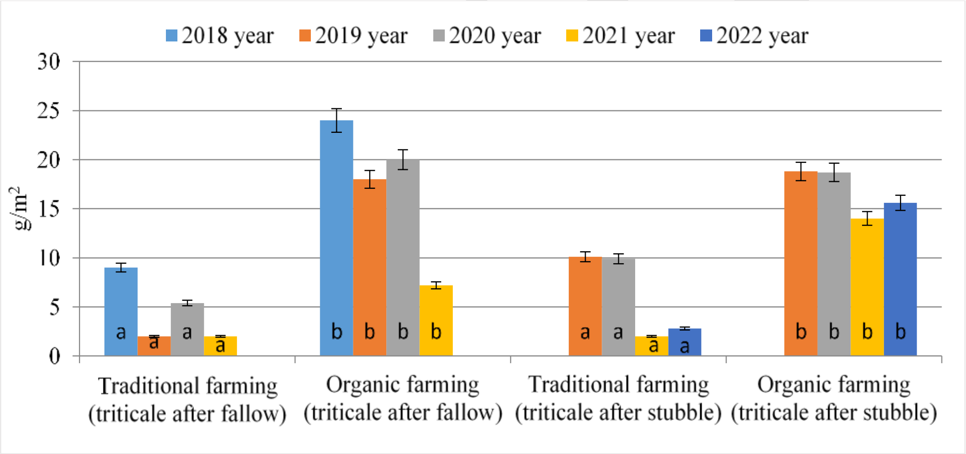

Fig. 4: Dry mass of weeds before harvesting triticale depending on the farming system and preceding crop (fallow and stubble). *Statistical significance at P<0.05.

Table 3: Triticale yield (t/ha) depending on the year, farming system, and preceding crop (fallow or stubble),t/ha (T - traditional farming, O - organic farming)

Treatments	T	O	T	O	T	O	T	O	T	O
	2018		2019		2020		2021		Average	
Triticale after fallow										
1. Control: P40 on fallow land (background)	$2.96a^{a}$	$1.95a^{b}$	$2.68a^{a}$	$1.78a^{b}$	$1.72a^{a}$	$1.10a^{b}$	$1.52a^{a}$	$1.01a^{b}$	$2.22a^{a}$	$1.46a^{b}$
2. Background+N20	$3.20a^{a}$	$1.79a^{b}$	$2.75a^{a}$	$1.45b^{b}$	$1.73a^{a}$	$1.01a^{b}$	$1.72a^{a}$	$1.02a^{b}$	$2.35a^{a}$	$1.32a^{b}$
3. Background+N40	$3.44a^{a}$	$1.62a^{b}$	$2.62a^{a}$	$1.44b^{b}$	$1.84a^{a}$	$1.30b^{b}$	$1.72a^{a}$	$1.04a^{b}$	$2.40a^{a}$	$1.35a^{b}$
4. Background+N60	$2.91a^{a}$	$1.77a^{b}$	$2.81a^{a}$	$1.51b^{b}$	$1.79a^{a}$	$1.16a^{b}$	$1.75a^{a}$	$1.07a^{b}$	$2.31a^{a}$	$1.38a^{b}$
5. Background+N80	$2.99a^{a}$	$1.95a^{b}$	$2.66a^{a}$	$1.68a^{b}$	$2.04a^{a}$	$1.06a^{b}$	$1.77a^{a}$	$1.18a^{b}$	$2.36a^{a}$	$1.47a^{b}$
Triticale after stubble										
Treatment	2019		2020		2021		2022		Average	
1. Control: yellow melilot biomass	$2.26a^{a}$	$1.04a^{b}$	$1.45a^{a}$	$0.90a^{b}$	$1.72a^{a}$	$1.06a^{b}$	$1.92a^{a}$	$1.25a^{b}$	$1.84a^{a}$	$1.06a^{b}$
2. Sainfoin biomass	$2.21a^{a}$	$0.94a^{b}$	$1.93b^{a}$	$0.75a^{b}$	$1.78a^{a}$	$0.96a^{b}$	$2.08a^{a}$	$1.21a^{b}$	$2.00a^{a}$	$0.97a^{b}$
3. Alfalfa biomass	$2.27a^{a}$	$0.93a^{b}$	$1.68a^{a}$	$0.76a^{b}$	$1.87a^{a}$	$0.99a^{b}$	$2.09a^{a}$	$1.29a^{b}$	$1.98a^{a}$	$0.99a^{b}$
4. Awnless brome biomass	$2.43a^{a}$	$0.95a^{b}$	$1.79b^{a}$	$0.77a^{b}$	$1.89a^{a}$	$0.97a^{b}$	$2.11a^{a}$	$1.20a^{b}$	$2.06a^{a}$	$0.97a^{b}$
5. Wheatgrass biomass	$2.37a^{a}$	$0.96a^{b}$	$1.71a^{a}$	$0.76a^{b}$	$1.84a^{a}$	$1.07a^{b}$	$2.14a^{a}$	$1.22a^{b}$	$2.02a^{a}$	$1.00a^{b}$

The same lowercase letter within the year and the farming system shows the absence of significant differences compared to the control treatment ($P<0.05$) according to the LSD; The same uppercase letter within a year shows the absence of differences between the farming systems ($p<0,05$) according to the LSD.

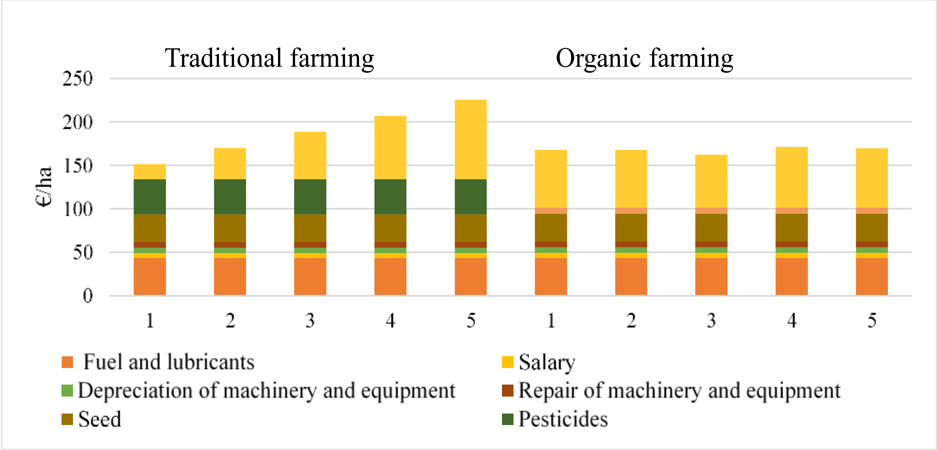

Fig. 5: Cost structure for the cultivation of spring triticale in traditional and organic farming systems (Treatments 1–5), €/ha

In traditional farming, the introduction of various doses of nitrogen after the fallow field as a preceding crop did not have a significant effect on the yield of triticale. After the stubble preceding crop, a significant increase in triticale grain in comparison with the control treatment was obtained only in 2020 in the treatment with N20 in the dose of 0.48t/ha, and a further increase in the dose of nitrogen fertilizers had no significant advantage.

In organic farming, the use of aboveground biomass of various perennial grasses had the same effect on the productivity of triticale. Exceptions were observed only in 2019 when the introduction of biomass of sainfoin, alfalfa, and awnless brome after fallow led to a decrease in triticale yield by 19, 18 and 15%, and in 2020 in the treatment with the introduction of the aboveground alfalfa mass, where grain yield increased by 18% compared to the control treatment.

The weather in the growing season had a much greater impact on the yield level of triticale. The maximum yield in the experiment was obtained in 2018 in the control treatment on fallow with traditional farming (2.96t/ha). In subsequent years, under more severe meteorological conditions, there was a decrease in yield in 2019 by 10%, in 2020 by 40% and in 2021 by 49%. A similar trend was observed with organic farming. After the stubble preceding crop in traditional farming, the highest yield in the control treatment was noted in 2019 (2.26t/ha). In 2020, it decreased by 36%, and in 2021 and 2022, by 24 and 15%. In organic farming, the change in the yield of triticale on stubble was less pronounced. In general, during the study period, there was no reliable effect of various doses of mineral and organic fertilizers on the productivity of spring triticale cultivated on fallow and stubble.

Economic Efficiency

The generalizing indicator of all activities carried out is the determination of economic efficiency, which allows us to give the most objective assessment of cultivation technologies. When calculating economic indicators, the costs of fallow preparation were proportionally (50/50) divided between the fallow and stubble preceding crop. The cost of triticale grain cultivated with traditional farming was 260€/t and with organic farming 328€/t.

Regardless of the preceding crop with traditional farming, the lowest costs for the cultivation of triticale were observed in the control treatment, where they amounted to 151.30 €/ha (Fig. 5). The largest part of the cost structure was the cost of fuel (43.39 €/ha), pesticides (40.58 €/ha), seeds (31.20 €/ha), and fertilizers (17.29 €/ha). Additional application of nitrogen fertilizer in doses from N20 to N80 led to an increase in fertilizer costs from 35.85 to 91.53 €/ha.

With organic farming, the costs of growing triticale in the experimental treatments fluctuated slightly and were in the range of 162.14-171.38€/ha. Fertilizers accounted for the biggest part of the cost structure (60.48-69.72€/ha), followed by fuel (43.52€/ha) and seeds (31.20€/ha). There was also such a specific item of expenditure as certification of organic production, which cost 7.5€/ha.

When cultivating triticale in traditional and organic farming, the costs of workers' salaries (5.5€/ha), wear and tear of machinery and equipment (6.23€/ha), and machinery repair (7.27€/ha) were the same. The highest indicators of economic efficiency, regardless of the preceding crop, were obtained in traditional farming, where the maximum net profit for fallow and stubble was obtained in the N20 application treatment (441.14 and 350.14€/ha) (Table 4).

In organic farming, the highest value of net profit was obtained on fallow in the treatment with the introduction of wheatgrass biomass (327.3€/ha). On the stubble preceding crop in organic farming, the highest profit was noted in the control treatment (190.68€/ha).

The most cost-effective way of triticale cultivation was noted in the control treatments, regardless of the studied farming systems. The profitability of the fallow preceding crop in traditional and organic farming was 282 and 194%, respectively, and for the stubble background, 216 and 114%, respectively.

The Content of Productive Moisture and Nutrients in the Soil before Sowing Spring Triticale

In the arid climate of northern Kazakhstan, the level of crop productivity largely depends on the availability of soil moisture before sowing (Zabolotskikh et al., 2021). In traditional and organic farming, regardless of the preceding crop, the content of productive moisture in the meter layer of soil was the same. This is because, under two farming systems, the same agrotechnical measures were carried out in the autumn, winter (chill, snow retention), and spring (moisture closure, pre-sowing treatment) periods. On the leached low-humus chernozem

Table 4: Conomic efficiency of spring triticale cultivation with traditional and organic methods, showing costs, income, profit, and profitability (T - traditional farming, O - organic farming)

Treatment	Costs, €/ha		Income, €/ha		Profit, €/ha		Profitability, %	
	T	O	T	O	T	O	T	O
Triticale after fallow								
1. Control: P40 on fallow land (background)	151.30	167.60	577.20	493.48	425.90	325.88	282	194
2. Background+N20	169.86	167.60	611.00	446.16	441.14	278.56	260	166
3. Background+N40	188.42	162.14	624.00	456.30	435.58	294.16	232	181
4. Background+N60	206.98	171.38	600.60	466.44	393.62	295.06	191	172
5. Background+N80	225.54	169.56	613.60	496.86	388.06	327.30	172	193
Triticale after stubble								
1. Control: yellow melilot biomass	151.30	167.60	478.40	358.28	327.10	190.68	216	114
2. Sainfoin biomass	169.86	167.60	520.00	327.86	350.14	160.26	206	96
3. Alfalfa biomass	188.42	162.14	514.80	334.62	326.38	172.48	173	106
4. Awnless brome biomass	206.98	171.38	535.60	327.86	328.62	156.48	159	91
5. Wheatgrass biomass	225.54	169.56	525.20	338.00	299.66	168.44	133	99

(Southern Forest-Steppe of Russia), it was found that when oat and wheat straw was applied in the amount of 1.78-2.28t/ha, soil moisture reserves were 7-12mm higher than the treatments without straw (Aisakulova et al., 2023). This was not been observed in our experiments.

The content of nitrate nitrogen for 2018-2021 before sowing triticale on fallow in traditional and organic farming varied within the limits of high (10-16mg/kg) and very high (>16 mg) availability. On stubble as the preceding crop, regardless of the farming system, the parameters were within the limits of medium and high levels.

The high and increased nitrogen content in the soil before sowing triticale by fallow in the studied farming systems is associated with multiple mechanical treatments that were carried out for weed control. Improvement of soil aeration during processing increased its microbiological activity (nitrification) contributing to the accumulation of a large amount of nitrate nitrogen in it. On stubble preceding crop, a good supply of nitrogen before sowing was associated with a low yield of spring triticale on fallow, as a result of which nitrogen removal from the soil was also low.

Considering that the region is characterized by a low level of precipitation and a non-washing soil regime, the main part of nitrates is always concentrated in the upper 0-40cm soil layer. Denitrification is also impossible due to the aridity of the climate. In addition, low temperatures in the autumn, winter, and spring period (up to 6 months), contribute to the freezing of the soil up to 1.5-2.0m, which fixes mineral nitrogen and stops all microbiological processes. During the short post-harvest and pre-sowing periods, mechanical tillage is carried out, which is accompanied by the introduction of crop and weed residues into the soil, for the decomposition of which microorganisms require additional nitrogen, which also minimizes its loss. Unused nitrogen (soil and fertilizers) is constantly in the arable layer or microbial biomass, and, consequently, with increased aridity of the climate, it will not significantly affect the pollution of groundwater and the atmosphere (Ndede et al. 2022).

The differences in the content of mobile phosphorus in the soil are more related not to the farming system, but to the soil variability of the experimental plots on which the studies were conducted. The P_2O_5 content in the 0-20cm soil layer before sowing triticale was in the range of 24-35mg/kg, which is the optimal amount for grain crops in the region (Kurishbayev et al., 2020). The optimal availability of P_2O_5 in the soil is associated with the intensive use of phosphorus fertilizers in the previous periods of use at the experimental site. The low yield of spring triticale and the short period of study could not lead to a significant change in the P_2O_5 reserves in the soil. The P_2O_5 reserve in the soil was replenished as well due to its application with fertilizers.

Thus, the content of productive moisture and nutrients in the soil before sowing triticale in traditional and organic farming was the same and could not affect the differences in the productivity of this crop. However, data from other studies indicated a positive effect of organic fertilizers on the content of nutrients in the soil and their absorption by plants. Although organic fertilizers do not contain more nutrients than traditional chemical fertilizers, they must undergo a process of conversion and decomposition before plants can absorb them. This difference may be one factor influencing changes in soil microbial communities. So, the application of clover green manure increased the content of nitrogen and phosphorus in the shoots and grain of wheat, and Arachis pintoi green manure increased the absorption of phosphorus from phosphate fertilizers applied to maize (Ma et al., 2024). Bi et al. found that a low-phosphorus organo-mineral fertilizer significantly increased soil phosphorus availability and resulted in higher rice yields than a conventional fertilizer. Different fertilization regimes significantly altered the abundance and composition of bacterial communities containing genes that regulate organic and inorganic P mobilization (Bi et al., 2019).

Also, numerous studies confirm that organic fertilizers contribute to increasing soil moisture. A single application of such fertilizers effectively retained water in the soil profile at a depth of up to 200cm, due to the high content of organic matter, which contributed to the strengthening of soil aggregates (Chen et al., 2022). This phenomenon indicates that the presence of organic matter in the soil has a beneficial effect on its ability to retain moisture. The lack of difference in soil moisture between traditional and organic fertilizers can be explained by the characteristics of low-humus chernozem. This type of soil has an alkaline pH, which affects the rate of decomposition of organic matter, since the rate of decomposition is higher, and organic matter content is relatively low in alkaline soil.

Weeds

The absence of weeds before sowing in traditional and organic farming is associated with the same set of technological operations that were carried out in the autumn after harvesting the preceding crop and in the spring when preparing the fields for sowing. In northern Kazakhstan, the spring period is often cold and weeds do not have time to grow due to a shortage of positive temperatures. Part of the weed vegetation is destroyed during pre-sowing cultivation (carried out 5-7 days before sowing), and the rest and fresh seedlings are removed when sowing triticale (seeders with cultivator working parts). Perennial weeds usually grow together with triticale seedlings, and annual weeds grow after productive precipitation. Control over the number of weeds is possible only with the use of herbicides in traditional farming, minimizing their impact on the growth and development of the cultivated crop. In organic farming, the use of herbicides is unacceptable. Therefore, cultivated plants compete with weeds for nutrients and soil moisture already in the initial period of their development, leading to a decrease in the productivity of triticale.

In the conducted experiments, a high level of weed infestation was observed in organic farming, which was several times higher than the threshold of harmfulness. This situation is not unusual for organic farming. The exclusion of herbicides and weed control only by mechanical tillage does not fully solve the problems with weed vegetation, and therefore, the fallow field is the only link in organic crop rotations where a significant reduction in the level of weed infestation is possible. For example, in organic farming of a vegetable farm in Dixmont, Maine, USA, the average number of weed seeds/m^2 in a 0-10cm soil layer is 25.000 seeds, which is several times higher than the threshold of harmfulness. In a survey of 23 organic farms in northern New England, USA, the germination density of weed seeds ranged from 2,500 to 25,000seeds/m^2. Eight of the 23 farms on average collected more than 10.000seeds/m^2, which indicates a strong weed infestation and impact on the yield (Gallandt, 2014).

The regulation of nutrients through fertilizers plays a key role in weed control in crops (Berquer et al., 2023; Nath et al., 2024). Other studies show that organic nutrient sources can either enhance or inhibit weed growth, creating synergistic or antagonistic effects. For example, the addition of vermicompost can either promote or inhibit weed growth (Manzoor et al., 2024). At the same time, substances such as brassica meal and neem cake exhibit allelopathic effects, affecting the germination of seeds of undesirable plants (Fodorpataki & Kulcsar, 2023). This research showed that the same organic fertilizer can have different effects on different weed species in maize growing. Repeated applications of nitrogen as a concentrated organic fertilizer showed a reduction in the density and biomass accumulation of the most dominant weeds such as Anagalis arvensis due to the release of allelochemicals into the soil. However, the use of organic manure did not have a significant effect on the growth of large-seeded weeds such as Vicia hirsuta and tuber-reproducing plants such as Cyperus rotundus (Khan et al., 2023). These results demonstrate the complexity of interactions between weeds and crop plants and their competition for fertilizer nutrients. Therefore, our results do not contradict other studies and demonstrate for the first time that organic matter made of green manure increases weed control in triticale crops.

Triticale Grain Harvest

Jiang and colleagues found that the use of organic fertilizers for maize in chernozem can lead to a small but significant increase in crop yields. This increase is comparable to the results achieved with traditional chemical fertilizers. The main reason for this effect is the ability of organic fertilizers to reduce the bulk density of the soil. This improves its porosity, which in turn facilitates more efficient nutrient uptake by plants. Thus, organic fertilizers not only increase crop yields but also improve soil quality, making them an important tool in modern agriculture. The use of such fertilizers can become a sustainable alternative to chemical analogues, promoting a more environmentally friendly approach to agronomy (Jiang et al., 2024). However, our data show the opposite effect of organic fertilizers.

When comparing farming systems by triticale yield, a decrease in yield was noted in organic farming. Since the development and spread of diseases and pests above the threshold of economic harmfulness were not noted during the study years, the most likely reason for this is high weed infestation due to the lack of herbicide treatments during the growing season.

The results obtained are confirmed by numerous studies when the yield of crops decreased during the transition to organic farming (Yakovlev et al., 2024; Nugmanov et al., 2023). For example, in developed countries, organic farming yields are 20% lower compared to intensive production systems (de la Cruz et al., 2023). The lack of nitrogen in the soil is often considered the main factor responsible for the low productivity of organic systems (Ansabayeva, 2023). However, in our case, as can be seen from Table 3, the crop did not lack nitrogen nutrition, as indicated by the absence of additions from fertilizers, both organic and mineral ones.

In studies conducted in Italy during the transition from traditional to organic farming, there was also a decrease in the yield of winter wheat and corn by 17%. The observed decrease in yield in 2019 was due to the activity of nitrogen mineralization with additional application of organic fertilizers after a high-yielding year and the restriction of its release due to unfavorable meteorological conditions (Suraganova et al., 2024). In our view, the most probable cause of the yield reduction in spring triticale is competition from weeds, which deplete essential resources such as moisture and nutrients, while also occupying physical space. This effect is particularly pronounced in treatments where triticale was sown on the stubble of the preceding crop, as these conditions resulted in the lowest yield and a significantly higher weed count, along with increased weed dry biomass. Spring triticale is a new crop in northern Kazakhstan, so the thresholds for the harmfulness of weeds have not yet been established for it. Considering that spring triticale is close to spring wheat in biology, the harmfulness of weeds may be the same. In northern Kazakhstan, with severe clogging (10pcs/m^2 or more) by perennial root weeds, the loss of spring wheat grain can reach 0.35-0.50t/ha (Karipov, 2019).

In the modern literature, many researchers point out the responsiveness of spring triticale to the application of mineral fertilizers (Sydiakina et al., 2018; Wysokiński & Kuziemska 2019). In northern Kazakhstan with traditional farming, the introduction of ammonium nitrate by fallow did not contribute to an increase in the yield of triticale. On stubble as a preceding crop, a reliable increase was obtained only in one of the three study years. This may be explained by the fact that due to the aridity of the climate in northern Kazakhstan, spring triticale cannot fully assimilate soil nitrogen. This is supported by the fact that before sowing spring triticale, 43.2-105.6kg/ha of nitrogen was contained in the 0-40cm soil layer (with a mass of 4.8 million kg/ha). This amount of nitrogen is sufficient to form a higher yield of triticale. Therefore, with the high nitrogen availability of the soil and harsh hydrothermal vegetation conditions, the additional use of nitrogen fertilizers is impractical. Similar results were obtained in South Australia, in arid conditions in the American Northwest, and in Siberia, where small doses of nitrogen are recommended to minimize risks (N 15-35kg/ha), and a further increase in nitrogen doses is ineffective (Sharkov, 2016; Madenova et al., 2019; Le Campion et al., 2020).

In organic farming, spring triticale on fallow and stubble responded equally to the introduction of an aboveground mass of various perennial grasses in the form of fertilizers.

The observed decrease in the yield of triticale over the study years with an increase in the aridity of the growing season indicates that with an increase in the aridity of the climate, we should expect a decrease in crop yields by two or more times in comparison with moistened years. This is consistent with numerous studies of the climate in Kazakhstan, which claim that increased aridity will lead to a decrease in crop yields (Karatayev et al., 2022; Babakholov et al., 2022; Guo et al., 2018; Ihsan et al., 2016). Therefore, the productivity of crops cultivated under organic farming conditions is subject to sharper fluctuations due to the influence of biotic factors (weeds, pests, and diseases).

Thus, it can be concluded that with increasing aridity of the climate, a decrease in the yield of spring triticale should be expected, regardless of the farming system. This decrease is most pronounced in organic farming due to insufficiently developed and imperfect methods of biological control of weeds, pests, and diseases. Organic farming is in a more vulnerable position compared to traditional systems, as it uses fewer ways to control weeds, pests, and diseases.

Economy

The farming system can be considered economically stable if the profit is high enough to conduct economic activity and can cover possible risks (Turebayeva et al., 2022). As our study showed, the existing risks in traditional and organic farming are primarily associated with weather that is unpredictable and does not lend itself to long-term forecasts. First of all, the level of grain yield is determined by the amount of precipitation falling in June and July (Karatayev et al., 2022), Considering that in the region, up to 80% of costs are formed already during the sowing period (May), when building a cultivation system, it is necessary to focus primarily on minimizing costs (profitability). For example, in traditional farming, the greatest net profit is obtained when nitrogen is applied in different doses, but no significant differences in yield were established. Therefore, the compared productivity options are at the control level, which means that the income from the sale of products should be the same. Accordingly, an increase in costs in comparison with control will always lead to a decrease in profit.

The cultivation of spring triticale in traditional and organic farming using fallow and stubble as preceding crops, regardless of the fertilizer option, provides high profits in northern Kazakhstan. Similar high-profit were obtained when growing winter wheat on dryland in southern Kazakhstan (Zhumatayeva et al., 2022).

In organic farming, there were no differences between the income options, since the triticale grain yield for all options was at the same level. The aboveground biomass of grasses like awnless brome and wheatgrass was more expensive than the biomass of legumes since it had to be applied more for the introduction of 16kg/ha of phosphorus. The most cost-effective option was the introduction of the aboveground mass of the melilot, where yields and income were higher and fertilizer costs were lower than other treatments.

When calculating costs, subsidies adopted in Kazakhstan for compensation of certain groups of pesticides (up to 30%), mineral fertilizers (up to 50%) for agricultural machinery, and aggregates (up to 25%) of their cost were not considered. Therefore, when using state subsidies, the costs of triticale cultivation in the two farming systems can be even lower.

When comparing farming systems, the most effective one was the cultivation of triticale in traditional farming (with the addition of phosphorus fertilizer to the P40 reserve), where the profitability was 282% for fallow and 216% for stubble. Regardless of the farming system, the greatest profitability was obtained when cultivating spring triticale on fallow preceding crop.

The low yield of triticale in organic farming is compensated by a higher price, which is formed for organic products. According to the Food and Agriculture Organization (FAO) data (FAO 2015), production costs (seeds, rent, repairs, etc.) in organic farming are significantly lower than in traditional systems and can vary for grains from 50 to 60%. This is primarily due to lower costs for pesticides, mineral fertilizers, and labor remuneration. Total costs (land fund, buildings, and equipment) may increase due to new investments or certification.

Thus, in northern Kazakhstan, with traditional farming, the greatest profit is formed due to productivity and lower costs and with organic farming, due to higher prices for final products.

Conclusion and Suggestions

The farming system did not affect the initial parameters of soil fertility. The content of productive moisture, nitrogen, and phosphorus in the soil was the same.

The productivity of triticale decreased with the deterioration of hydrothermal conditions, regardless of the farming system and the preceding crop. The yield of spring triticale, regardless of its preceding crop, was always higher in traditional farming.

We established that from an economic point of view, spring triticale is profitable for cultivation both in traditional and organic farming systems. However, a large economic benefit is obtained when it is cultivated in traditional farming with the introduction of the recommended dose of amorphous P40.

The use of the aboveground mass of various types of perennial grasses as an organic fertilizer had the same effect on the productivity of triticale. The maximum economic efficiency in the organic cultivation system was obtained in the treatment with the introduction of aboveground biomass of yellow melilot.

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