

The influence of agrometeorological factors on the yield of grain crops in the forest-steppe of the Omsk region

L.V. Yushkevich, D.N. Yushchenko, A.G. Shields, S.P. Kashinskaya, and A.S. Butko*

Omsk Agricultural Research Center, Omsk, Russia

Abstract. In the arid agricultural landscapes of Western Siberia, the productivity of leading grain crops is determined by adaptive agrotechnology, the use of intensification tools and hydrothermal conditions. The relatively low (up to 1.40-1.70 t/ha) and unstable yield of grain crops is mainly due to the limited use of fertilizers (up to 20 kg/ha), the aridity of the climate. Long-term studies have established that in the southern forest-steppe agricultural landscapes, precipitation of all periods of the year, except for spring, has an impact on grain productivity. Autumn moisture reserves determine the yield of spring wheat after its corn predecessor by 51% in general, up to 21% for steam, and only 13% for barley. The conjugacy of spring soil moisture is higher on wheat, on flat-cutting processing than on plowing, on intensive agrotechnology. The most significant combination of spring moisture reserves and summer precipitation (June-1st decade of July). The dependence of wheat yield after steam reaches a high conjugacy ($r=0.77-0.84$), after corn – from medium to strong (up to 59-71%). The correlation of yield with the temperature regime during the growing season is negative. The conjugacy with the value of GTK is more pronounced after the corn precursor – 46%, steam – up to 30%, barley only 8%, the greatest dependence was revealed with the Coefficient of dryness. The predicted yield level of high-quality grain with complex chemicalization and soil protection treatment with average long-term hydrothermal parameters on wheat after the corn precursor reaches 2.8 t/ha with a probability of up to 76%, and 3.4 t/ha for steam. To optimize the water regime, it is necessary to use additional moisture-accumulating agricultural techniques.

1 Introduction

The vast region of Western Siberia is located in arid agricultural landscapes with a continental climate with cool and little snow in winter, short summer and spring periods. The continentality of the climate increases in the territory with the advance from north to south [10, 8].

The purpose of the research. To identify patterns of the influence of hydrothermal conditions on the productivity of grain crops in arid agricultural landscapes of Western Siberia.

* Corresponding author: yushchenko@anc55.ru

2 Materials and methods

Over a long period (15 years) of zonal and stationary observations, data from water balance points in the Omsk region, including in the southern forest-steppe zone – Isilkul, Omsk, Kalachinsk, were analyzed. In the steppe zone – Poltava, Russian Glade, Cherlak. To establish conjugate links between hydrothermal conditions and soil moisture, data on grain yield in stationary (since 1972) field crop rotation on crops: spring wheat for two precursors and barley were taken. The repetition of the experience is 4 times. Observations and mathematical processing were performed using generally accepted methods [4]. The soil of the experimental field is meadow–chernozem heavy loamy with a humus content of 6-7%.

It has been established that the southern regions of Western Siberia have insufficient and unstable moisture content: from 50 to 70% of precipitation falls in summer and 20-25% from the beginning of the year to March. Summer precipitation is mainly agronomically low-value (less than 5 mm), the largest amount falls in July – up to 70-75 mm. The snow cover forms in the first decade of November and reaches up to 25-30 cm by snowmelt. A significant amount of annual precipitation in the territory falls in the region in a band from 65 to 67 ° north latitude. The main climatic features of soil-climatic zones are presented in Table 1.

Table 1. Climatic features of the Omsk region

Soil and climate zone	precipitation		The sum of temperatures >10 °C	Frost-free period, day	Period from t°C above 10° C, days	humidification by precipitation
	annual expenses	for the growing season				
Northern forest steppe	380-450	220-250	1800-2100	110-120	120-130	0,60-0,65
Southern forest steppe	330-380	170-220	2000-2200	120-130	125-135	0,50-0,60
Steppe	280-330	160-200	2150-2250	125-135	130-140	0,45-0,50

3 Results

Over the past 15-20 years, the yield of grain crops, especially in the steppe regions, averaged 1.50-1.80 t/ha, which is not enough. The main reason is the violation of agricultural technologies, extremely low fertilization and aridity of the climate. More severe weather conditions in recent years in the Omsk region developed in the five-year period 1996-2000, when the yield of grain crops in most areas did not exceed 1.20-1.50 t/ha (Yushkevich et al., 2021).

It is established that the influence of hydrothermal conditions in the formation of grain yield in arid conditions is unequal. A preliminary analysis of the conjugacy of moisture, precipitation of various periods and yields, which were cited from agricultural reports and statistical data, showed that in the southern forest-steppe zone, the conjugacy of precipitation and yield is weaker than in the more arid agro-landscapes of the steppe zone. Winter precipitation determines the yield of grain crops by 6.2%, in the steppe – 19.6%, during the growing season, respectively, 27.7 and 28.8%, July by 27.0 and up to 64.0%. Early observations in the steppe Russian-Polyansky district established that before the development of virgin land, the dependence of grain yields on precipitation was closer than after the development [12].

Hydrothermal conditions have a significant impact on the yield, adaptability and ecological plasticity of spring wheat varieties. It has been established that the productivity of grain crops largely depends on the agrotechnology of cultivation in specific agricultural landscapes [1, 5, 7].

In the southern forest-steppe zone, observations have shown that precipitation in all periods of the year, with the exception of spring, has a noticeable effect on the productivity of grain crops. Weak conjugacy of yields during dump and flat-cut processing is manifested with winter precipitation (November-March), winter-spring (XI-V), autumn (IX-X), and generally non-seasonal ($r=0.30$). The higher influence among non-seasonal precipitation is autumn-winter ($r=0.34$). It was revealed that autumn moisture reserves have a more stable effect on the yield of grain crops (Table 2).

Table 2. Correlation (r) of grain yields with autumn humidity in a layer of 0 – 1.0 m, depending on agricultural technologies (southern forest-steppe), n=11.

Aption	Wheat by steam		Wheat by corn		Barley	
	the system of tillage in crop rotation					
	plowing	flat-cut	plowing	flat-cut	plowing	flat-cut
Without chemicalization (control)	0.34	0.35	0.66	0.52	0.19	0.08
Herbicides	0.36	0.69	0.80	0.62	0.26	0.37
Fertilizers	0.21	0.56	0.81	0.83	0.45	0.38
Fertilizers+ herbicides	0.39	0.78	0.73	0.75	0.48	0.66
Average	0.32	0.60	0.75	0.68	0.34	0.37

In autumn, the moisture content of the meter layer in steam was 102-108 mm, on corn – 55-64 and barley – 41-49 mm. A higher dependence of autumn soil moisture on the yield of wheat placed in pairs on flat-cut processing was manifested against the background of the use of fertilizers and herbicides ($r=0.78\pm0.21$), after corn - on flat-cut processing against the background of fertilizers ($r=0.83\pm0.18$). In general, autumn moisture reserves affect grain yields, on spring wheat after corn by 51%, on steam – up to 21% on barley – only 13%.

Spring moistening of the soil for sowing grain crops is the most important prerequisite for the formation of the yield level and should be up to 120-160 mm in a meter layer. For southern forest-steppe and steppe agricultural landscapes, productive moisture reserves of less than 100 mm are unsatisfactory, less than 60 mm as "threatening" [3,15].

It should be noted that previously conducted observations have not established a stable relationship between spring moisture and grain yields in the Altai Territory [9].

Observations in stationary experiments have shown that with unreliable forecasts for summer precipitation, spring moisture reserves are more significant, but their dependence on yield is largely determined by technological factors (Table 3).

Table 3. Correlation (r) of grain productivity with spring humidity in a layer of 0-1.0 m, depending on agrotechnology (southern forest-steppe), n=11.

Option	Wheat by steam		Wheat by corn		Barley	
	the system of tillage in crop rotation					
	plowing	flat-cut	plowing	flat-cut	plowing	flat-cut
Without chemicalization (control)	0.11	0.45	0.41	0.48	-0.10	-0.16
Herbicides	0.52	0.60	0.33	0.61	0.32	-0.02
Fertilizers	0.37	0.47	0.22	0.70	0.25	-0.09
Fertilizers+ herbicides	0.56	0.67	0.26	0.72	0.50	0.46
Average	0.39	0.55	0.31	0.63	0.24	0.05

It was found that the conjugacy of wheat productivity with spring soil moisture is observed on wheat after corn, on soil protection treatment with fertilizers and complex

chemicalization – $r=0.70\pm0.23-0.72\pm0.23$. Consequently, wheat yield by 49-52% was determined by spring humidity, and a closer relationship is traced not with the meter, but with the upper (0-50 cm) a layer of chernozem soils. Increased conjugacy in variants with the use of chemicalization agents is associated with the elimination or reduction of the influence of additional factors affecting crop productivity (nutritional regime, contamination of agrophytocenosis). The decrease or absence of a conjugate relationship between moisture and barley productivity is mainly due to its drought resistance.

For grain crops, the "critical" period of greatest moisture demand falls on the formation of generative organs, it usually occurs 10-15 days before earing and 5-10 after earing [6]. It was found that for the formation of high plant productivity, the total combination of spring humidity and vegetation precipitation of yield with the complex use of chemicalization agents is of particular importance. The dependence on steam is strong ($r=0.77-0.84$), medium ($r=0.61$) and strong ($r=0.74$) on wheat after corn (up to 59-71%).

In the zone, positive temperatures during the growing season are 2000-2250 °C, above 10 °C – 125-140 days with a GTC of 0.90–1.10, atmospheric droughts have not been rare in recent years. Its main feature is an increase in anticyclonic activity with a prolonged (more than 20 days) absence or minimal loss of agronomically low-value (up to 5 mm) precipitation. The increased temperature period in June-July is often combined with active winds and dust storms (2020-2023). The prolonged absence of rain increases the negative impact of high temperatures, especially at night, when grain plants do not even have a temporary rest.

During the growing season in Omsk there are 35 days with a maximum temperature of 25.0-30.0 °C, more than 10 days – from 30 to 35 °C, mostly the hottest is July. It has been established that the ratio of various grain crops to the temperature regime is unequal and, in general, it has a negative effect on grain yield. According to the coefficient of determination, it is 25% for wheat by steam, 31% after corn and less than 10% for barley.

It was revealed that there is a stable relationship between the productivity of grain crops and the hydrothermal coefficient (GTC), in June it is more pronounced than during the growing season (Table 4).

Table 4. Dependence of grain yield on the GTC indicator (June), (southern forest-steppe).

Option	Wheat by steam		Wheat by corn		Barley	
	the system of tillage in crop rotation					
	plowing	flat-cut	plowing	flat-cut	plowing	flat-cut
Without chemicalization (control)	0.50	0.58	0.64	0.55	0.23	0.13
Herbicides	0.38	0.54	0.61	0.65	0.32	0.26
Fertilizers	0.64	0.72	0.75	0.79	0.26	0.22
Fertilizers+ herbicides	0.50	0.56	0.69	0.72	0.46	0.34
Average	0.51	0.60	0.67	0.68	0.32	0.24

It was revealed that wheat yield depends on the SCC (June) by 34% on annual plowing, and 41% on flat-cutting processing. A closer dependence on the SCC is observed in wheat after corn – 46%, for a couple it decreases to 30%, for barley, mainly due to its higher drought resistance, it is only 8%. During the growing season (June-August) The correlation of the yield of spring wheat with the value of GTC decreases relative to June from an average of 37.8 to 22.3%.

The use of chemicals has a certain positive effect on the conjugation of SCC with the yield of spring wheat, which is mainly due to the additional influence of the contamination of agrophytocenosis, nutritional regime. So, in general, in the variant without chemicalization and with the use of herbicides, the conjugacy is up to 33%, with complex chemicalization, the conjugacy reaches 38-52%.

The dryness coefficient takes into account soil moisture before sowing, precipitation during the growing season or calendar month and the average daily air temperature [2]. It was found that the dependence of wheat yield on dryness, strong, and with complex chemicalization, reaches 50-80% ($r=0.78\pm0.19$ and 0.90 ± 0.14), (Table 5).

Table 5. Conjugacy (r) of grain yields with dryness (June) depending on agrotechnology (southern forest-steppe), n=11.

Option	Wheat by steam		Wheat by corn		Barley	
	the system of tillage in crop rotation					
	plowin g	flat-cut	plowing	flat-cut	plowing	flat-cut
Without chemicalizatio n (control)	0.39	0.45	0.89	0.87	0.40	0.22
Herbicides	0.44	0.35	0.82	0.90	0.34	0.37
Fertilizers	0.66	0.62	0.78	0.84	0.41	0.41
Fertilizers+ herbicides	0.50	0.47	0.83	0.87	0.38	0.33
Average	0.50	0.47	0.83	0.87	0.38	0.33

It takes 1750 °C for spring wheat to mature from sowing to waxy grain ripeness. According to long-term observations, in the southern forest-steppe and steppe zones, the sum of effective temperatures is 1900-2200 °C, over the past 50 years they have increased to 2000-2250 °C. In this regard, there is practically no shortage of effective and active temperatures in the southern forest-steppe and steppe agricultural landscapes. At the same time, 19 droughts have been observed over the past 50 years, including 12 of moderate intensity, including the last period (2020-2023).

Based on long-term observations, the yield of grain crops under various agrotechnologies and hydrothermal conditions in southern forest-steppe agricultural landscapes, it is possible to predict potential productivity. Thus, with moisture reserves in the meter layer for wheat sowing up to 150 mm (87% NIP) for the steam precursor, 100 mm (60% NIP) for corn, the precipitation rate in June (55 mm), the average annual air temperature (18 °C) at an agrophone with complex chemicalization, it is possible to obtain a yield of high-quality grain after the corn precursor, 2.8 t/ha with a predicted probability of up to 76%, for wheat by steam – 3.4 t/ha.

The practice of soil protection agriculture shows that moisture is the basis of the harvest. In this regard, in order to increase the effectiveness of agricultural technologies in arid agricultural landscapes, it is necessary to use moisture storage techniques (the optimal share of the steam field in the structure of arable land is up to 16-18%, mechanized snow retention UVS – 9.0, stubble of increased cut, the use of combing harvesters, sowing of wings, mulching of soil, improvement of technical means, etc.) [11, 13, 14].

4 Conclusion

Thus, in the arid agricultural landscapes of Western Siberia, the hydrothermal conditions of vegetation, autumn and spring moisture reserves, precipitation, air temperature, hydrothermal coefficient – GTK, determine the yield of grain crops, and their influence in field crop rotations with various agrotechnologies is unequal. A closer correlation between the yield of spring wheat and barley is observed with a complex indicator – the dryness coefficient (according to A.V. Bova). With the use of complex chemicalization and soil protection tillage, average long-term hydrothermal parameters, the predicted yield level of high-quality spring wheat grain after the corn precursor is 2.8 t/ha with a probability of up to 76%, for a pair of

3.4 t/ha. It is necessary to use additional moisture-accumulating agricultural techniques (recommended specific gravity of vapors, mechanized snow retention, high-cut stubble, combing harvesters, backstage, mulching, improvement of technical means).

References

1. L.P. Baykalova, Yu.I. Serebrennikov, *Bulletin of KrasGAU*, **8**, 3-11 (2023). DOI: 10.36718/1819-4036-2023-8-3-11
2. N.V. Bova, *The climate of the south-east of the European part of the USSR* (Saratov, 1961) 134.
3. N.I. Buyankin, V.N. Slesarev, *Degradation and ecologization of Siberian chernozems*, Russian Academy of Agricultural Sciences, monograph (Kaliningrad, Yantarny Skaz, 2006) 192.
4. B.A. Dospekhov, *Methodology of field experience* (M., Kolos, 1979) 416.
5. S.V. Zharkova, E.I. Dvornikova, *Bulletin of the Altai State Agrarian University*, **11 (181)**, 10-17 (2019).
6. A.A. Zhuchenko, *Adaptive plant breeding system (ecological and genetic foundations)*, monograph, In 2 vols. 1.1 (M., RUDN, 2001) 780.
7. I.A. Korchagina, L.V. Yushkevich, *Wheat varieties in intensive agriculture of the Omsk Irtysh region*, monograph (Omsk, Omsk Federal State Budgetary Scientific Institution "Omsk ANTS", 2023) 172.
8. A.R. Makarov, [et al.]. *Soil moisture resources in arid agriculture of Western Siberia*, monograph (Omsk, 1992). 146.
9. V.G. Kholmov, L.V. Yushkevich, *Intensification and resource conservation in agriculture in Western Siberia*, monograph (Omsk, Publishing house of FGOU VPO OmGAU, 2006) 396.
10. I.F. Khramtsov, V.S. Boyko [et al.], *Omsk Agrarian Center*, 522 (2020).
11. M.S. Chekusov [et al.], *Agriculture*, **3**, 13-16 (2016).
12. M.E. Cherepanov, *Snow retention in soil protection agriculture of Western Siberia*, monograph (Novosibirsk, Science, 1988) 160.
13. L.V. Yushkevich, I.V. Pakhotina, A.G. Shchitov, *Bulletin of KrasGAU*, **7 (172)**, 26-34 (2021). DOI: 10.36718/1819-4036-2021-7-26-34
14. L.V. Yushkevich, A.A. Kem, *Bulletin of the Altai State University*, **4 (102)**, 084-088 (2013).
15. L.V. Yushkevich, I.V. Pakhotina, V.V. Chibis, *AgroEcoInfo*, **2 (32)**, 7 (2018).