Conference Paper

Adaptation of Technological Methods to Climatic Conditions in Agrotechnologies in South Ural

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Abstract

This study aimed to define an optimal sowing date of winter wheat in the steppe zone of South Ural and West Siberia. The effects of climatic factors were determined by analyzing modern climatic resources and experimentally testing in the conditions of the central zone in Orenburgskaya oblast. Research from the All-Russian Scientific-Research Institute of Hydro-meteorological Information – World Data Center (RSRIHI-WDC) served as a source of archival meteorological data for 2009-2019. Experimental data were collected through field work on the south chernozem in the Central zone of Orenburgskaya oblast for 2019-2020. Digital material was processed using statistical analysis. It was confirmed that in the Central zone of Orenburgskaya oblast under modern climatic conditions, the period between 25-30 August is the most acceptable date to sow winter wheat. If sowing occurs at later dates, there is a risk of not obtaining the required amount of effective temperatures, which can result in disunited sparse shoots, bushes that are not fully formed, and low phytometric parameters, and therefore a low realization of climatically secured productivity. These results could be more widely tested in other steppe regions of Ural and West Siberia with a prospect to introduce the results into zonal recommendations for production.

Keywords: climatic resources, productivity reserves, winter wheat

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1. Introduction

Restoration of soil fertility and conservation of biological diversity in the post-virgin land regions of Ural and West Siberia that had undergone a considerable anthropogenic load during a period of their reclamation should go, perhaps, on the way of optimization of an agricultural land use structure and ecologization of plant growing. Their nature is to transfer underproductive arable lands into foraging areas, to concentrate technological costs on the best lands, to adopt landscape-adaptive systems of agriculture and nature-similar resource-saving technologies directed to form high balanced and stable agrolandscapes [1]. Under this approach it is less feasible to guarantee a food secure for population without adaptation of technological approaches in zonal agro-technologies to modern climatic resources in order to increase efficiency of their use on soils suitable for tillage.

The principal supplier of food grain in the studied regions of RF is traditionally considered spring wheat. Under the modern tendency of warming and aridity's growing its productivity and gross grain harvest considerably vary. An increase of a winter wheat portion which has higher potential of productivity in comparison with spring wheat, in the technological context providing a rational calendar use of agricultural machinery as well as more accurate maintenance of technological discipline, offers a considerable reserve to increase gross grain harvest [2-6]. Predominance of winter wheat in the structure of crops in such universally recognized steppe granaries of the European part of Russia as Krasnodarsky and Stavropolsky Krays, Rostovskaya, Volgogradskaya and Saratovskaya oblasts, confirms this fact [7, 8]. In the steppe agrarian areas of South Ural and West Siberia which are weighty suppliers of high-quality grain to Russian and foreign market, a rise of grain production of winter wheat is restricted by low adaptivity of practiced technologies to dynamic climatic factors. Their total limiting influence is accompanied by a considerable dynamics of sowing areas and grain productivity, especially for last decades characterized by considerable climatic and anthropogenic transformations.

The current situation is a cause of concern between grain producers and the scientific society who undertake special efforts to adapt technological methods to modern climatic conditions and stabilize grain production in this region. Thus, in accordance with stable climate warming which has been noticed for last decades, scientist-agrarians and farmers have a firm belief to move sowing dates of winter crops to later time. Higher defeat of early seeding by diseases and pests [9], a risk of plant overgrowing due to fast gain of the demanded sum of effective temperature because of an increase of its average daily values and following higher death during the winter are the principal arguments to confirm this offer. Also, increasing aridity in August that prevents to form unite and dense shoots, first of all under traditional water-wasteful approaches of cultivation in crop rotation, is a reason to move a sowing date for winter crops to the beginning of autumn.

It should be mentioned that a choice of an optimal sowing date and degree of autumn vegetation of winter wheat in farms within the steppe zone of RF is very significant. As it well known, a special significance of the autumn period is connected with a fact that it is laid a basis to form a future structure of an agrocenosis and its total productivity

[10, 11]. Also, a success of overwintering depends on a sowing date as plants which had formed well bush, but not started booting yet, developed 3-4 strong shoots of tillering by the end of vegetation and gone through I and II phase of hardening, overcome winter hardships more successfully [9, 12].

Thus, in the steppe zone of South Ural and placeWest Siberia under a visible dynamics of climatic factors effecting on terms of autumn vegetation of winter crops a fixing of optimal sowing dates for winter wheat has a high topicality. Their selection and scientific explanation would promote to stabilize harvests and croppage in modern climatic conditions.

The aim of the study is to analyze and estimate modern climatic resources as well as to explain and test experimentally optimal sowing dates for winter wheat on the example of the Central zone of Orenburgskaya oblast in order to level the limiting effect of climatic factors and form stable and high productive agrocenoses.

To achieve the goal the following tasks were formulated:

- to study modern resources of effective air temperatures (more 5°C) in the Central zone of Orenburgskaya oblast for the more possible period of the autumn vegetation of winter wheat;

- to define optimal rated sowing dates for winter wheat under modern climatic conditions;

- to estimate a state of agrocenoses with winter wheat sown in different dates for various vegetation periods and their phytometric parameters taking into account Normalized Difference Vegetation Index (NDVI);

- to analyze given results and denote the most acceptable sowing time to test it in production conditions.

2. Methods and Equipment

Special information for climatic researches of All-Russian Scientific Research Institute Hydro-meteorological Information –World Data Center (RSRHI-WDC) served as a source of archival meteorological data on the air temperature regime for 2009-2019 [13]. Experimental data was received in the course of field work on the south chernozem in the Central zone of Orenburgskaya oblast for 2019-2020. Soil of the experimental plot is characterized by humus content 4.5 mg and 27 mg at 100 g of soil, respectively. Two varieties of soft winter wheat Kolos Orenburzhiya (The Ear of Orenburgskaya oblast) by Orenburg SAU's selection from the list of agricultural crops included in the RF State

Registry and admitted to use in Orenburgskaya oblast in 2013 and a new variety Rifey tested in 2019 were examined. Autumn tillage of fallow field was made by "Smaragd" cultivator at the depth of 10-12 cm. Four layer-by-layer surface cultivations by the KPS-4 engine were carried out during the summer to clear the fallow from weeds, the last cultivation was made at the depth of covering of seeds. A sowing with a norm of 4.5 million germinable seeds at 1 ha was conducted using the AUP-18.05 machine by means of broadcast seeding in two dates - 26 August and 13 September.

To monitor phytometric parameters of experimental plots with winter wheat was defined Normalized Difference Vegetation Index (NDVI) by portable device (manual sensor) Green Seeker Handheld Crop Sensor, Model HCS -100 (Trimble, USA).

Generally accepted methods of the statistical analysis were used to process digital material.

3. Results and Discussion

It is generally known that the minimal temperature of air for winter crops assimilation is 4-5°C when physiological processes in plants are still active and their growth and development is lasting. In the late-autumn period since transition air temperature of +5°C to transition temperature 0^0C, poor vegetation might be noticed only in day hours characterized by a short-term increase of warm. There, visible changes in a degree of plant vegetation are not seen [14].

In the period of active adoption of intensive technologies (1985-1990) into RF agrarian production which were directed to realize in the maximum a potential ability of adaptive varieties, the optimal sowing date for winter crops in the Central zone of Orenburgskaya oblast was considered the second decade of August (11-20 August). Agricultural practice of that time confirmed optimality of the mentioned period to form high-productive agrocenoses.

Our study conducted for the following period (1993-1998), under the already formed tendency of climate warming in the Central zone of Orenburgskaya oblast, promotes to ascertain that winter wheat should be sown between 23-28 August to form 3-4 strong sprouts of tillering. In this case autumn vegetation lasts 50-55 days, and the sum of average daily temperature from shoots to stable transition of +5°C reaches 471-574°C [5].

The best sowing date, according to our data, coincides with fixing of average daily air temperature at the level 17-15°C. The earlier sowing leads to plant overgrowing, their transit to spring stages of organogenesis that is fraught with unfavorable overwintering.

Later shoots do not have time enough to form bush, have low productive bushiness and less assimilation surface, lag behind and are not able to realize climatically secured productivity [15].

The similar results were obtained by other scientists, for example Zelenev A.V. and his colleagues (2016) noted that winter wheat sown too late sprouted longer, did not have time to form bush, develop good root system and above-ground mass. It often leads to considerable shortage of harvest [8].

The study of modern resources of effective temperatures (more 5°C) in the Central zone of Orenburgskaya oblast conducted by us (2009-2019) for the most possible period of autumn vegetation of winter wheat (15.08-25.10) did not reveal positive dynamics of its sum, and represented even some tendency to decrease (Figure 1).

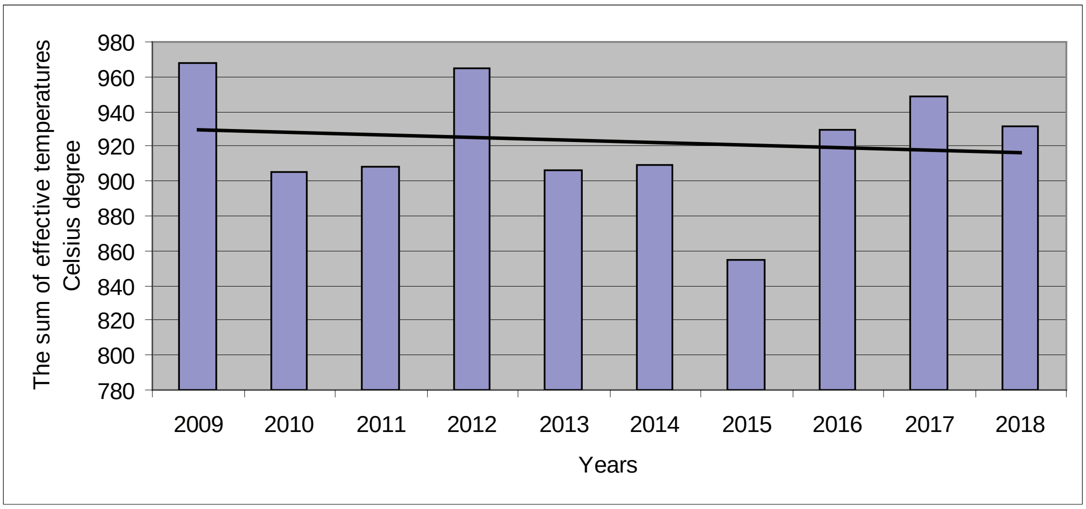

Figure 1: The dynamics of the sum of effective air temperatures (more 5°C) in the Central zone of Orenburgskaya oblast for the most possible period of autumn vegetation of winter wheat, 2009-2018

The most stable sum of effective temperatures with the coefficient of variation 9.4% was noticed in September. In August a degree of data dispersion was moderate and characterized by the coefficient of correlation 12.4%. The most changeable thermal resources were in October when the sum of average daily temperature more + 5°C varied from 102°C in 2015 to 207°C in 2019 (Table 1).

According to results of modern resources of the effective temperatures, we revealed dates of transition average daily temperature of +5°C and calculated optimal dates of seedling emergence which, were, in average, between 31 August and 5 September for 10 years. Under more considerable variation of a date of transition average daily temperature of +5°C between 8 October in 2015 and 29 October in 2019 (22 days), rated optimal dates of seedling emergence were more stable. Their variation was only 9 days – since 28.08 -3.09 in 2015, 2016 and 2019 to 5.09-10.09 in 2009 and 2018.

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Table 1: Optimal rated sowing dates for winter wheat in modern climatic conditions in the Central zone of Orenburgskaya oblast

Years	The sum of effective temperatures (more 5°C) for the period, °C			A date of transition average daily temperature of +5°C	The rated period of seedling emergence	The optimal rated period of sowing
	15-31.08	1-30.09	1-25.10			
2009	322	460	186	21.10	5.09 - 10.09	30.08 - 4.09
2010	357	437	111	13.10	29.08 – 3.09	23.08 – 28.08
2011	297	433	178	16.10	1.09 – 6.09	26.08 – 31.08
2012	362	403	200	22.10	3.09 – 9.09	28.08 – 2.09
2013	338	422	146	20.10	31.08 – 5.09	25.08 – 30.08
2014	405	383	121	18.10	29.08 – 3.09	23.08 – 28.08
2015	277	456	102	8.10	28.09 – 3.09	23.08 – 28.08
2016	404	400	126	9.10	28.08 – 2.09	22.08 – 27.08
2017	385	429	135	19.10	31.08 – 5.09	25.08 – 30.08
2018	310	434	188	26.10	5.09 – 10.09	30.08 – 4.09
2019	327	321	207	29.10	28.05 – 2.09	22.08 – 27.08
Average	343	419	154	20.10	31.08 – 5.09	25.08 – 30.08
Coefficient of variation	12.4	9.4	24.7			

Taking into account the average duration of seedling emergence (by 6-7 days after the sowing), in modern climatic conditions in the Central zone of Orenburgskaya oblast optimal rated sowing dates for winter wheat fall at 25-30 August. The results of field research has been conducted in 2019-2020 confirmed the mentioned sowing dates; the field experiment showed that due to a shortage of effective warm the later sowing would lead to form poor developed sparse shoots even under the sufficient amount of precipitation (Figure 2).

a b

Figure 2: A state of agrocenoses with winter wheat before the end of autumn vegetation under various sowing dates: 26 August (a), 13 September (b).

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When the sowing date was 13 September and seedling emerged 19-20 September, even under long period of autumn vegetation (to 29.10), the sum of effective temperatures was equal only 282°C that was lower than optimal values at 189°C (40.1%)-292°C (50.8%). There was not a shortage of precipitation in presowing and after sowing periods. Thus, 37 mm precipitation was recorded for August and the first half of September, and 35 mm precipitation fell in the rest September.

On our opinion, the reason of poor autumn development of plants was a shortage of warm due to frequent and long periods of average daily temperatures reduction in the period after the sowing. The most considerable reduction of the temperature was noticed since 18 September to 1 October when in separate days average daily temperature of air decreased lower +5°C, and 24 September it was only +3.6°C (Figure 3).

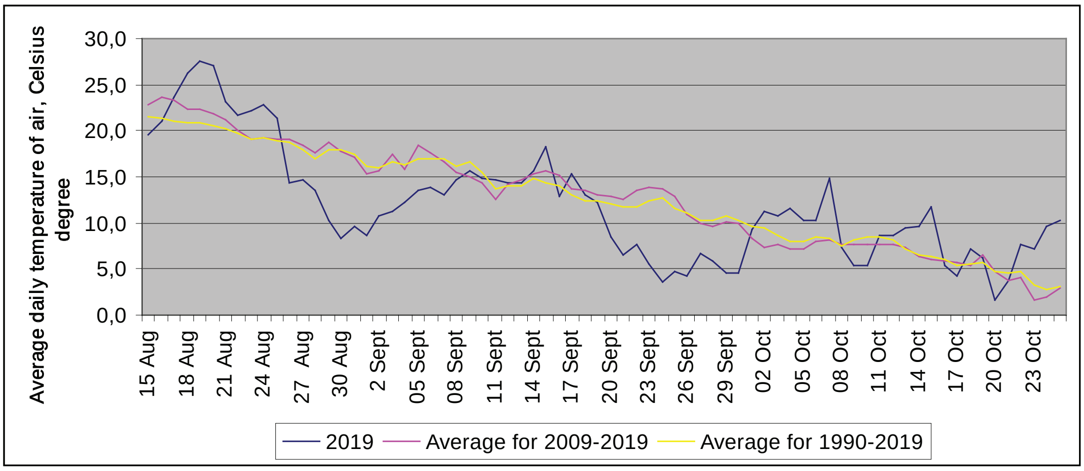

Figure 3: The dynamics of average daily temperatures of air in the autumn, 2019

In spring months after renewal of active vegetation started 23 March, the increased temperature of air promoted to pass quickly through stages of organogenesis and did not promote additional tillering (Figure 4).

As it well known, productivity of crops in a considerable degree is defined by the photosynthetic activity of shoots, and it is in a tight relation with their phytometric parameters – a square of the assimilation surface and photosynthetic potential [15], in turn, correlating with Normalized Difference Vegetation index (NDVI).

Results of our assessments concerning a state of agrocenoses with winter wheat for different sowing dates and periods of vegetation as well as control of their phytometric parameters according to Vegetation Index (NDVI) revealed its considerable variation between compared sowing dates in 2019 (Table 2).

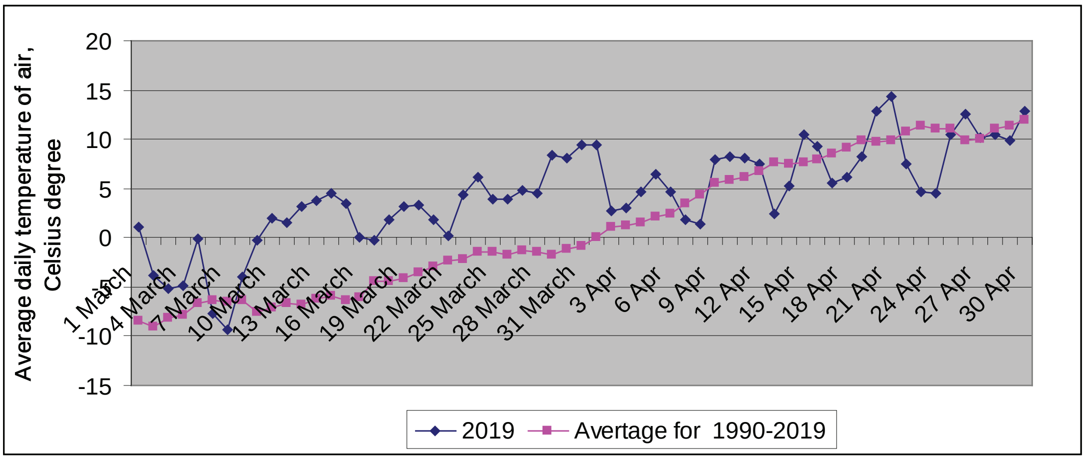

Figure 4: The dynamics of average daily temperatures of air for the early-spring period, 2020.

Table 2: Phytometric parameters of agrocenoses of winter wheat with different sowing dates

Sowing date	Vegetation index (NDVI) according to stages of winter wheat vegetation				
	Autumn tilling (the end of vegetation)	Spring tilling (renewal of vegetation)	Leaf-tube formation	Ear formation	Flowering
26 August	0.70	0.77	0.80	0.77	0.72
13 September	0.37	0.49	0.59	0.62	0.57

In agrocenoses with optimal sowing dates (26 August) Normalized Difference Vegetation index (NDVI) was close to indicators of high-productive crops and exceeded the similar indicator of later shoots (13 September) during the whole vegetation. It shows high productivity of phytomass expressed in the optimal density of plant stand and its best leaf formation.

In the whole, results of the analysis of modern meteorological data (2009-2019) conducted by us promote to conclude that under the total tendency of climate warming in the Central zone of Orenburg Pre-Ural region, there is not noticed a considerable increase of the sum of effective temperatures for the autumn vegetation of winter wheat. There is a tendency of the gradual rise of average daily temperatures in August that under its high absolute values substantiates a necessity to move a sowing date to later time. Results of field experiment confirmed validity of expressed arguments that might be considered as a base to test them more thoroughly in other steppe regions of Ural and placeWest Siberia and adapt to zonal recommendations for production.

Revealed tendencies have a special significance for ecologically oriented optimization of the steppe land use structure assuming to withdraw degraded lands from cultivation, to allocate the most valuable, in the landscape aspect, countries and areas and to intensify agriculture on soils suitable for cultivation using innovative digital technologies [1].

4. Conclusion

In modern climatic conditions in the Central zone of Orenburgskaya oblast the most optimal sowing date for winter wheat is a period between 25-30August. A sowing in the mentioned dates under the tendency of a temperature increase in August promotes to avoid to overgrowing and high death of plants during winter time. If one is interested in later sowing date, a risk will increase not to get full amount of effective temperatures, to obtain disunited sparse shoots, plants which formed not enough bushes and are characterized by low phytometric parameters, and, as a result, low realization of climatically secured productivity.

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Conflict of Interest

The authors have no conflict of interest to declare.

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