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Climatic Change Impact on the Grain Crops' Yielding Capacity at Various Soil Cultivation Ways within Crop-Sugar Beet Rotation Agrocenoses in the Left-Bank Ukrainian Forest-Steppe

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Aim. To estimate the influence of contemporary climatic changes to the forming of the cereal crops productivity (winter wheat and corn) depending on the adaptive measures system (fertilizer, cultivating, crop rotation type) in the agrocenoses of the Central Left-Bank Ukraine's Forest-Steppe. **Methods.** On the basis of long-term (35-40 years) investigations in the multifactor stationary field experience, the dynamics of the cereal crops productivity depending on cultivation, crop rotation type and fertilizer has been analyzed. The influence of meteorological indices on the nature of a trends' temporal movement in the cereal crops productivity has been modeled. **Results.** The effective use of an excess heat resource is connected to the introduction of mineral and organic fertilizers subject to different cultivation methods in various crop rotation types. For the crop rotation with the perennial grass at treatment with 6 t/ha of manure and average dose of fertilizers, the productivity of winter wheat, independent of the cultivation method, was 4.69 t/ha, barley – 4.54 t/ha; whereas during 2001–2010 due to replacement of manure with side-line products – 4.21 and 3.37 t/ha respectively, i.e., less by 0.48 and 1.17 t/ha. The productivity of spring barley, as compared to the manure treatment period, has reduced in average by 0.66 t/ha, or by 23.8 per cent; alongside, it remained highest at the deep subsurface loosening of soil. Return from the applied fertilizers proved to be higher by 123 per cent independent of the method of treating the soil. In five-plot pea-including crop rotation the average productivity of winter wheat in 2001–2010 decreased by 1.09 t/ha, or by 20 per cent. The most considerable reduction in the grain productivity has been fixed at both the subsurface and surface loosening of soil. As for the crop rotation with the perennial grass, on the contrary, a more considerable drop in the productivity was at ploughing (-0.59 t/ha). The corn productivity in the crop rotation with the perennial grass grew at various cultivation methods by 1.71 t/ha average, and in the pea-including crop rotation – by 1.95 t/ha. **Conclusions.** Excess heat resource during 2001–2013 in conditions of the Left-Bank Ukraine's Forest-Steppe zone anticipates in raising tempos the forecast scenarios of the climatic change until 2025 and needs the introduction of the adaptive agriculture system: the application of differing-depth cultivating for the chernozems with the precise following of the postharvest cultivation technological operations in the summer-autumn period together with the simultaneous basic autumn treatment with both organic and mineral fertilizers, however, without the basic dose treatment with the mineral fertilizers for spring cultivation, and also applying of green-manured fallows in the structure of planted areas. Under the contemporary conditions, the climatic change, in particular, an increase in the temperature in the center part of the Left-Bank Ukraine's Forest-Steppe favorably affects an increase in the productivity of the existing hybrids of corn, whereas the descending general trend has been observed during entire exploration period for the winter wheat and barley productivity because of an increase in the temperature of air to the critical values in the period of earing and grain pouring. The excess heat resource is effectively used by the contemporary middle- and of late-ripening corn hybrids, for which the conditions of optimum soil and atmospheric moisture supply in the "windburn" are created period of ardent and winter ear crops. That contributes to the growth of their productivity.

Keywords: grain crops, winter wheat, heat resource, subsurface loosening, grain-hoeing rotation, organic fertilizers.

INTRODUCTION

The global warming in the Ukrainian Forest-Steppe is of no doubts for any more [1, 2] and is considered as the experimentally proven fact in evidence. The research of this problem started in the pre-vious century [3]. According to the forecasts [4], a very rapid growth in the temperature of air during the vegetal period is provided to the middle of the 21st century, which corresponds to the assumed substantial increase in the population and with respect to the growing need for a quantity of foodstuff. The forecasted climatic changes must be of the vivid seasonal and regional nature, which requires the more thorough analysis of the already existing climatic situation, in particular, in the Central Left-Bank Ukraine's Forest-Steppe. Its detailing will make it possible to reveal the anticipating rates of raise in climatic indices towards the critical levels of warming. On the one hand, it is necessary to use an additional heat resource effectively, decreasing the risks of an increase in the temperature due to the introduction of the adaptive measures system [5, 6], and, on the other, to ensure the regional and national food safety through the stabilization of grain economy [7, 8] taking into account the processes of the chernozems progressive degradation [9, 10] in the Ukrainian agriculture.

The aim of the current research consisted in the evaluation of the influence of the contemporary climatic changes upon the cereal crops productivity forming (winter wheat, spring barley and corn), depending on the adaptive measures system (fertilizer, cultivation, crop rotation type) in the agrocenoses of the Central Left-Bank Ukrainian Forest-Steppe.

MATERIAL AND METHODS

The research has been carried out in the conditions of the center section of the Central Left-Bank Ukrainian Forest-Steppe by means of the long-term stationary experience at the Drabiv experimental plot of the Cherkassy State Experimental Station NNTS within NSC "Institute of Farming Agriculture NAAS". The experiment has been performed on the typical low-humus great-dusty light-clay chernozem with the humus content of 3.8–4.2 per cent, dynamic phosphorus – 12–14 mg in 100 g of soil, dynamic potassium – 8–10 mg in 100 g of soil, $pH_{salinity}$ = 6.8–7.0. Two types of five-plot crop rotation: 1) pea-winter wheat-sugar beet-corn-corn (60 per cent – grains, 20 per cent – legumes, 20 per cent – industrial plants); 2) perennial grasses-winter wheat-sugar beet-corn-barley with grasses sowing (60 per cent – grains, 20 per cent – industrial plants, 20 per cent – perennial grasses). Treatment system: without fertilizers and $N_{33\text{-}66}P_{31\text{-}62}K_{41\text{-}82}$ per 1 ha of the crop rotation + 6-7 t/ha of side-line products. Cultivation methods in the five-plot crop rotations: depth-varying ploughing for 22–25 cm; depth-varying subsurface loosening for 22-25 cm and shallow subsurface loosening for 10–12 cm. The weather data during the experimental period (1998–2013) were obtained from the Cherkassy Regional Weather Service.

RESULTS AND DISCUSSION

In last 35 years in the Central Left-Bank Ukrainian Forest-Steppe, whereto the Drabiv, Zolotonosha and Chornobayivka Districts of the Cherkassy Region are geographically located, the average-daily air temperature reached –2.4 °C in winter, whereas the standard is –4.2 °C. A quantity of winter sediments was lowered by 24 mm. Within the winter period, the sum of minus temperatures grew up warmer by –274 °C, only 69 per cent of sediments fall out. The average-daily air temperature in spring grew by +0.9 °C, and relative to values during 1913–1976 – by +1.7 °C. The summer period became warmer by +1.8 wasps, and average-daily temperature reached +20.4 °C, whereas the standard is +18.8 °C. Autumn grew warmer by +0.5 °C, and entire warm period of a year – by +0.8 °C. Substantially (by +987 °C) the sum of efficient temperatures within the warm period of a year grew, spring grew warmer to +85 °C; summer – by +802 °C, autumns – by +101 °C. The sum of effective temperatures increased in summer by +256 °C.

During 2001–2010 the average annual air temperature increased by +1.1 ºC, and within the warm period – by +1.4 ºC. The greatest increase in the average-daily air temperature is noted into the summer and autumn periods – by +1.6 and +1.4 ºC respectively, and within the spring period – by +0.5 ºC. The sum of active and effective temperatures during 2001-2005 grew up by 112 and 103 per cent, during 2006-2010 – by 117 per cent. For 10 years of experiments the sum of efficient temperatures increased by +430 ºC, and effective ones – by +358 ºC. That indicates essential worsening in the weather regime of the warm period of year towards increase in the aridity. Average annual total precipitation proved to be above standard by 47 mm, and in the warm period it remained within the limits of standard. Within the spring period the sediments fell out by 38 mm less, in summer - higher by 14 mm, for autumn – higher by 21 mm, while for winter – by 50 mm.

During 2001–2010 the temperature regime at the mentioned part of the Central Left-Bank Ukrainian Forest-

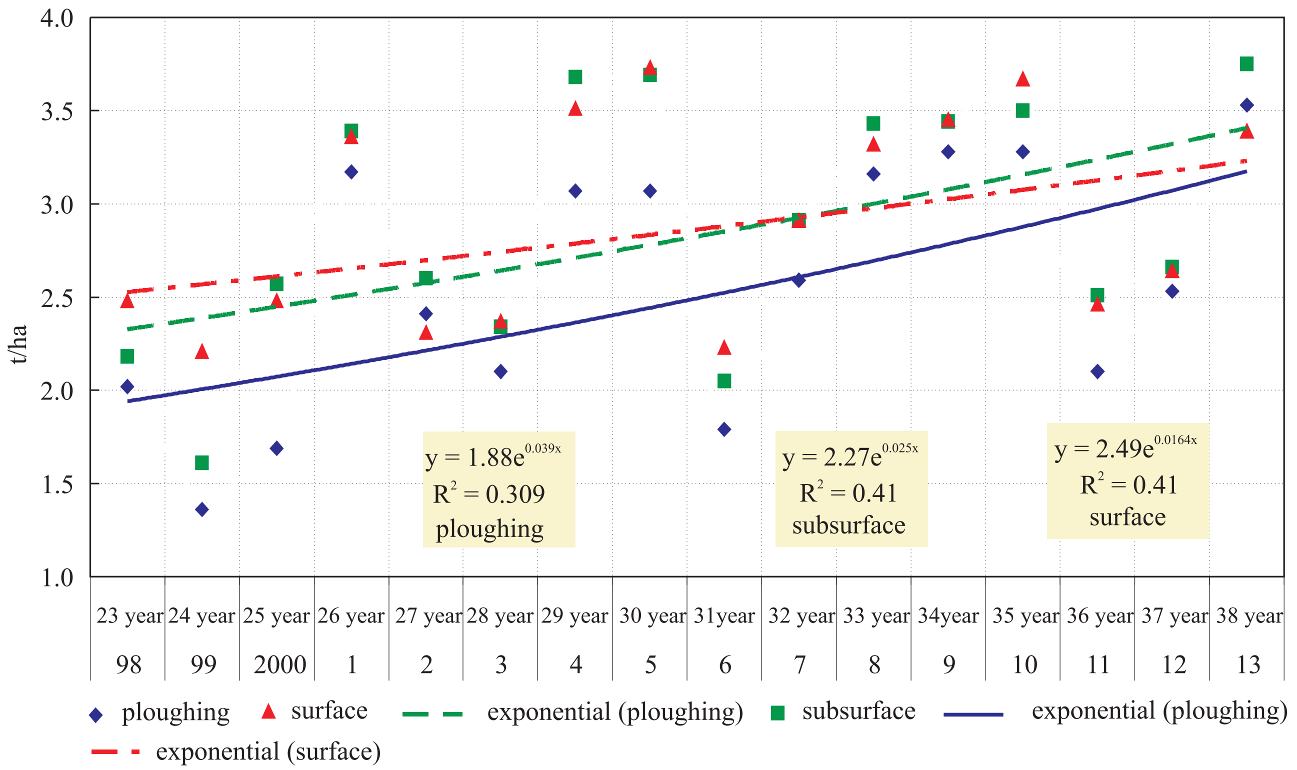

Fig. 1. Averaged trends in the winter wheat productivity increase without fertilizers (control) in the crop rotation agrocenoses in the Left-Bank Ukrainian Forest-Steppe, 1998–2013

Steppe exceeded the indices of the efficient temperatures sum provision (> 5°C) of the Southern Left-Bank Ukrainian Forest-Steppe in 1982-1992 both according to the normative indices and current ones, and as for the effective temperatures sum (> 10°C) approached them. Upon conditions of the Left-Bank Ukrainian Forest-Steppe the scenario of the change in the weather regime during the observation period corresponds to the raise tempos of the temperature conditions (concerning the sum of active and effective temperatures) as this is shown in the dedicated sources [4, 5].

During 1998–2013 an increase in the winter wheat productivity is established against the background of natural fertility (control without the fertilizers) (Fig. 1). A more intensive increase in the productivity is fixed on the systematic subsurface and surface cultivating relative to ploughing. That corresponds to the value of absolute term in the exponential equations of the trends, which are higher in 1.21-1.33 times. However, an increase in the productivity at ploughing is also of high intensity due to higher in 1.56–2.44 times regression coefficients in the exponential equations of trends. The average productivity depending on cultivating grew in 2.1 times and reached 3.06 t/ha. The average productivity of winter wheat since the beginning of this research was 3.86 t/ha in 1998, that is higher by 120 per cent (+0.62 t/ha), and as for the cultivating methods the harvest of grain was higher at subsurface one (3.75–3.80 t/ha) as in 1998-2013 (3.14–3.18 t/ha).

For a period of 27 years, since the beginning of the research, the dynamic numbers of a change in the winter wheat productivity (control, without fertilizers) was of descending nature, whereas during last 10 years – of ascending one. However, during entire period of explorations (38 years) the trends of the winter wheat productivity appeared to be descending (Fig. 2). The comparative estimation of the equations of the regression in the productivity trends for the regression coefficients at the variable in the last 10 years stated that the most efficient increase in the winter wheat productivity was at the subsurface cultivating, then – at the shallow subsurface one, and finally, – at ploughing (Fig. 1).

At ploughing the productivity was 2.61 t/ha; at the subsurface cultivating – 2.77 t/ha; at the surface one – 2.91 t/ha. In the crop rotation with the perennial grass the tendency toward an increase in the productivity at the subsurface cultivating has been revealed. After 22 years since the beginning of the experiment (until 1998) the winter wheat productivity in the crop rotation

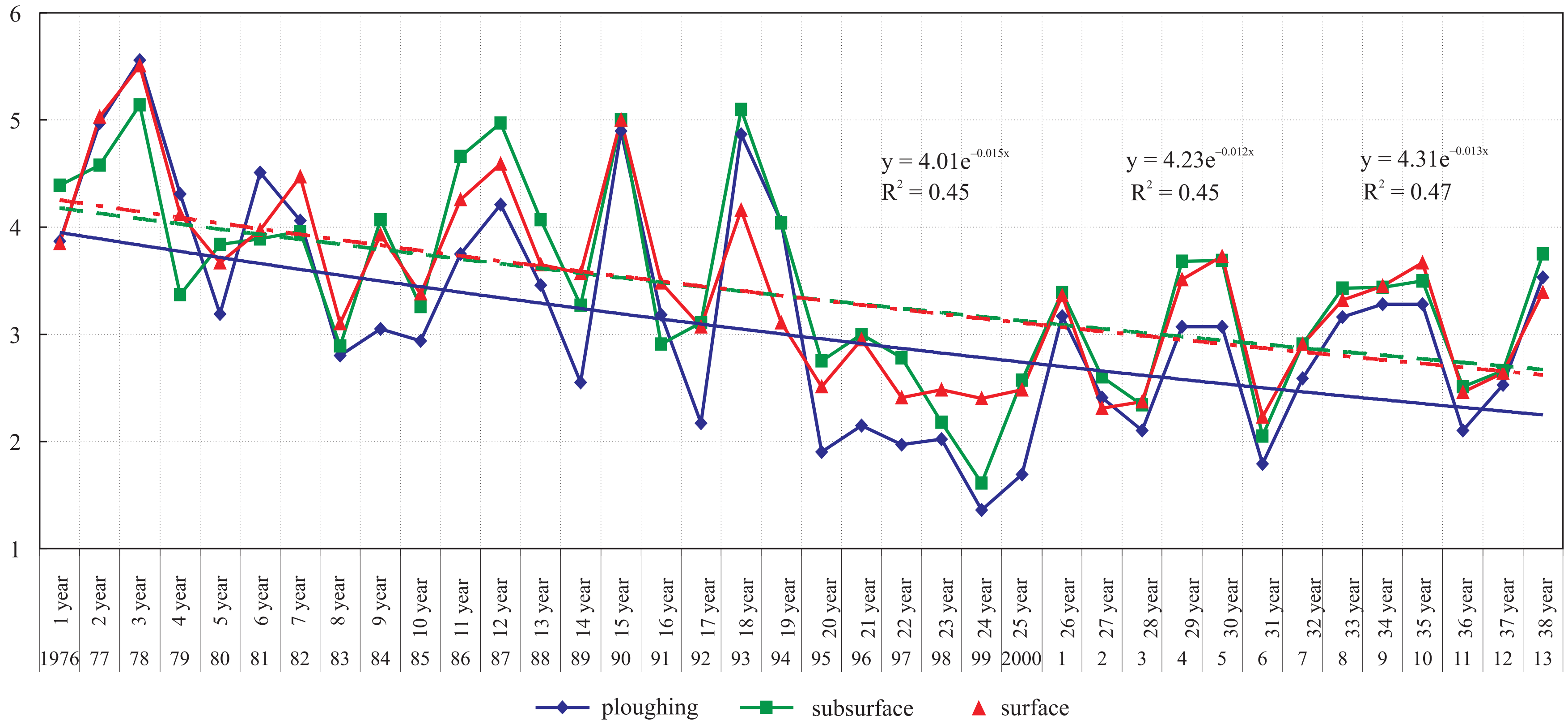

Fig. 2. Long-term influence of various cultivating methods at light-humus typical chernozems upon the winter wheat productivity in the five-plot crop rotations without fertilizers

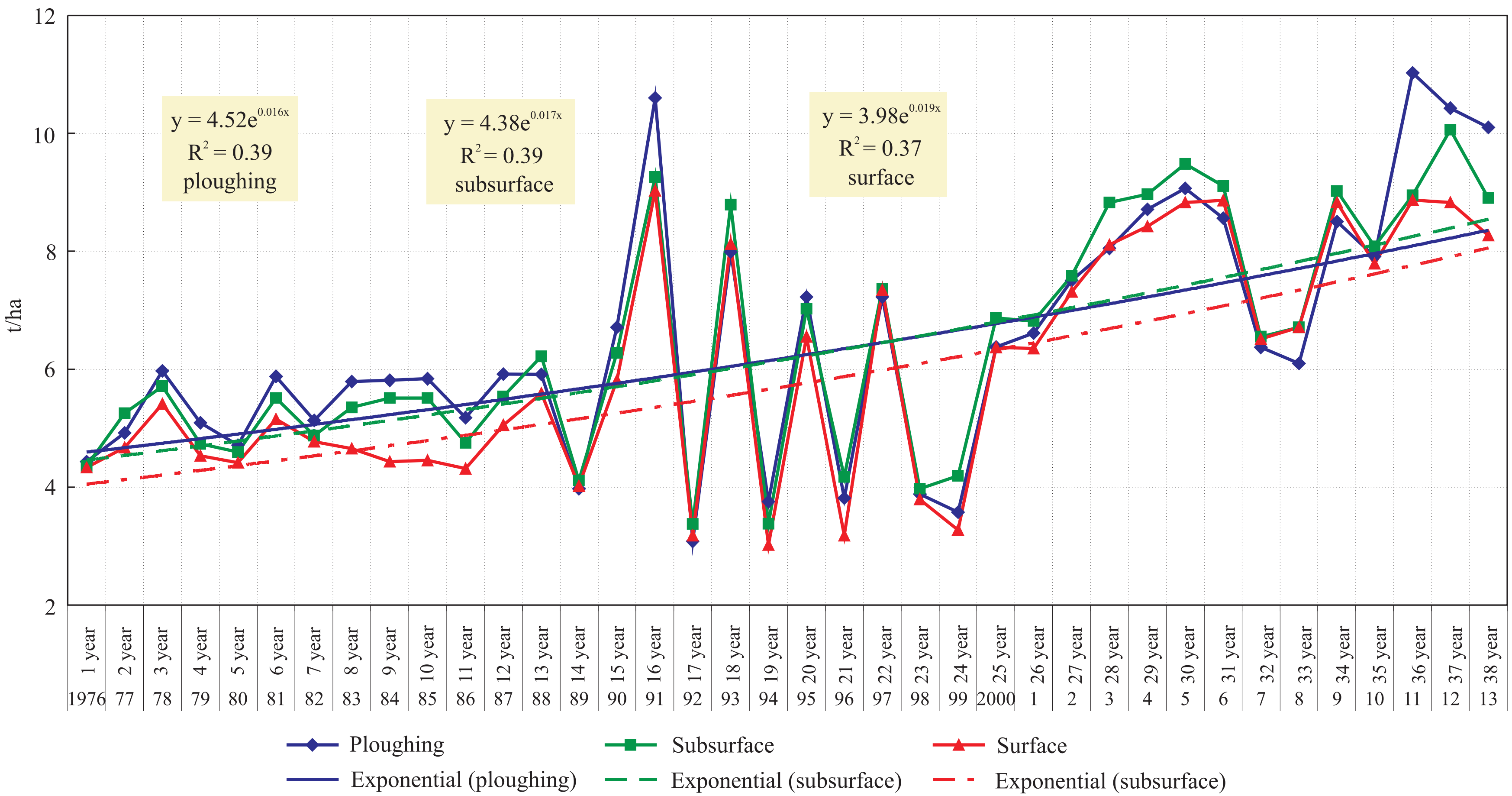

Fig. 3. Long-term influence of various cultivating methods at light-humus light-clay typical chernozems upon the corn productivity at treatment with $N_{66}P_{62}K_{82}$ (average values for various crop rotations types)

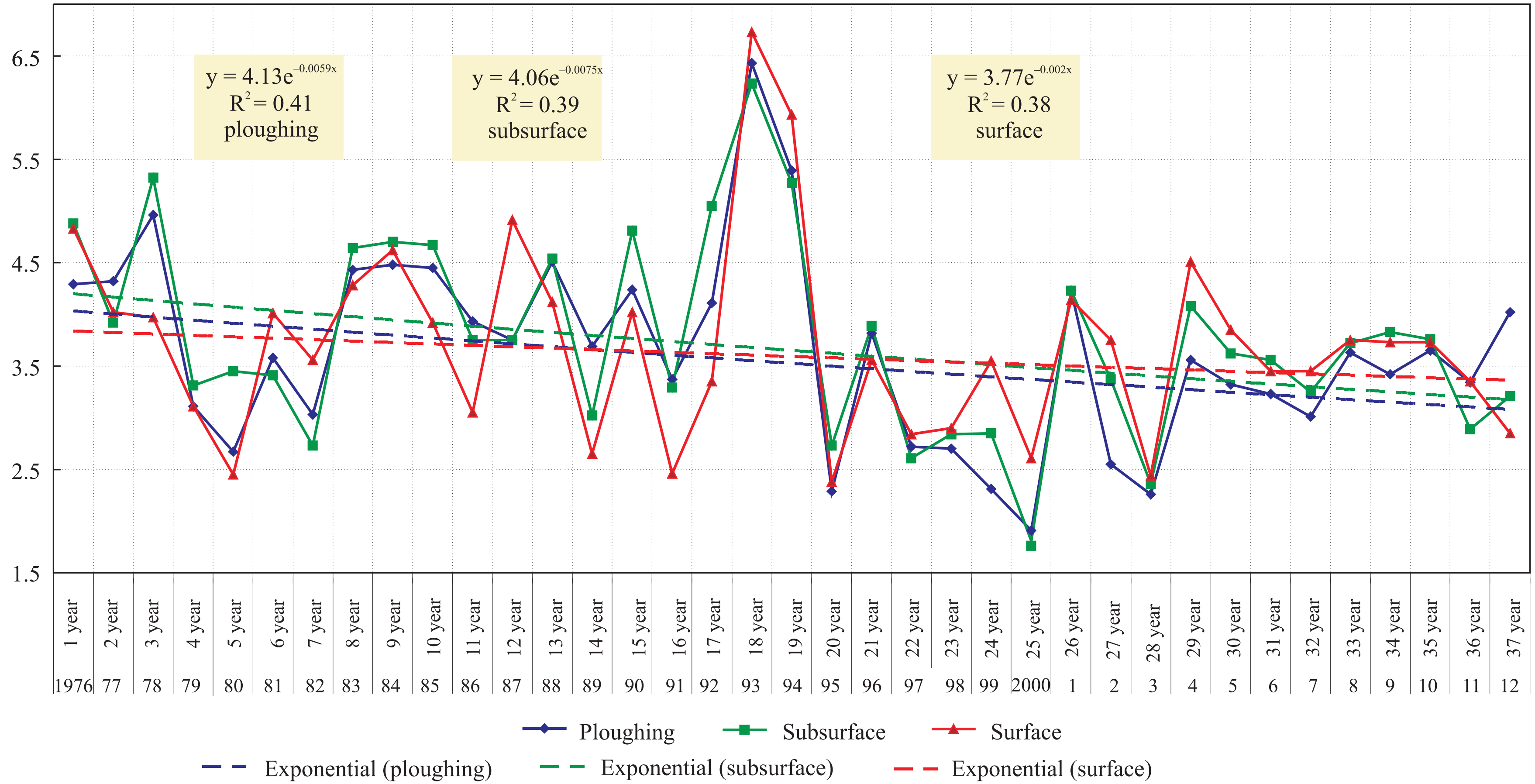

Fig. 4. Long-term influence of various cultivating methods at light-humus typical chernozems upon the spring barley productivity in the five-plot crop rotation with perennial grasses at treatment with $N_{33\text{-}66}P_{31\text{-}62}K_{41\text{-}82}$

with the perennial grass in the average at various cultivating methods was 3.96 t/ha, and within 2001–2010 – 3.04 t/ha or, by 23 per cent less.

The statistical analysis stated that during 37 years in the control experiments without fertilizers the maximum-typical winter wheat productivity in the average at various crop rotations at subsurface loosening was 4.04–4.91 t/ha, and at systematic ploughing – in 1.05–1.12 times lower. At the systematic surface cultivating the reduction in productivity was less than at the ploughing, and in comparison with the subsurface loosening a decrease composed 1.05–1.08 times. The minimum-typical winter wheat productivity changed within: 1.91–2.17 t/ha at the ploughing, 2.34–2.78 t/ha at the subsurface loosening, 2.41–2.64 t/ha at the shallow subsurface loosening. At the ploughing the reduction in the productivity was 1.23–1.28 times relative to the subsurface cultivating.

In the first case (ploughing), as for the minimum and maximum interval of values, the productivity was lower at the reliable level, whereas in the second case (surface cultivation) there was a steady tendency toward decrease. The variability of the productivity relative to average meaning at the ploughing was 33–34 per cent, at the subsurface loosening – 24–26 per cent, and finally, at the surface cultivating – 23–24 per cent.

In the pea-including crop rotation the winter wheat productivity decreased by 1.21 t/ha or, 23–24 per cent in average during 2001–2010, while the most considerable decrease proved to be at systematic ploughing (–0.86 t/ha) and surface cultivating (–1.5 t/ha). Higher productivity at the subsurface loosening should be explained not only with additional heat resource, but also high level of potential fertility formed during 37 years of subsurface loosening [9].

Grain Crops Productivity (t/ha) in the Five-Plot Grain-Hoeing Rotations Depending on Fertilizer and Cultivation Method upon Conditions of the Left-Bank Ukrainian Forest-Steppe

Crop Plants Crop Rotations	Ploughing 22–25 cm	Subsurface Loosening, depth		Ploughing 22–25 cm	Subsurface Loosening, depth		HIP
		22–25 cm	10–12 cm		22–25 cm	10–12 cm	
	Manure Treatment Period			Straw Treatment Period			
Control – neither organic, nor mineral fertilizers							
Grains – to 60 %, industrial plants – to 20 %, perennial grasses – to 20 %							
Grain crops, including	3.97	4.03	3.85	3.43	3.85	3.82	0.35
Winter wheat	3.67	4.15	4.07	2.71	3.16	3.25	0.45
Barley	2.51	2.99	2.81	1.96	2.21	2.17	0.55
Corn	5.72	4.95	4.66	5.62	6.16	6.05	1.25
Grains – to 60 %, industrial plants – to 20 %, legumes – to 20 %							
Grain crops, including	4.15	4.35	4.38	4.28	4.71	4.57	0.45
Winter wheat	3.74	4.28	4.45	2.88	3.05	2.95	0.35
Corn	4.51	4.35	4.38	5.67	6.35	6.25	1.15
$N_{33-66}P_{31-62}K_{41-82}$ Treatment							
Grains – to 60 %, industrial plants – to 20 %, perennial grasses – to 20 %							
Crop Plants Crop Rotations	6 t/ha of manure			7 t/ha of side-line products			HIP
Grain crops, including	5.35	5.17	4.75	5.21	5.15	5.02	0.65
Winter wheat	4.85	4.65	4.58	4.29	4.21	4.15	0.46
Barley	4.41	5.16	4.06	3.38	3.41	3.32	0.65
Corn	6.85	5.72	5.65	7.92	7.81	7.62	1.45
Grains – to 60 %, industrial plants – to 20 %, legumes – to 20 %							
Grain crops, including	5.77	5.75	5.15	6.07	5.95	5.95	0.65
Winter wheat	5.25	5.95	5.13	4.32	4.38	4.35	0.35
Corn	6.35	5.55	5.18	7.83	7.55	7.55	1.17

The corn productivity in 2001–2010 grew at both subsurface and surface treatment by +1.21 and +1.39 t/ha, whereas at the systematic ploughing it had a tendency toward decrease. Within the entire period of experiment the highest corn productivity was after the ploughing (6.52 t/ha), at the subsurface loosening the productivity was reduced to 6.47 t/ha, and at the surface treatment – 6.03 t/ha (HIP_{05} = 0.24 t/ha). The corn productivity trends were of the increasing nature independent of the cultivating method. According to the significance index (R^2) of the equation of the trends regression is reliable. The productivity trend at the subsurface loosening is most rapidly-growing. The maximal-typical interval of the corn productivity values at the ploughing was 7.99–10.1 t/ha, at the subsurface loosening – 8.79–9.55 t/ha, and at the shallow subsurface – 8.11–8.83 t/ha. The minimal-typical interval at the subsurface loosening was 8.82–9.55 t/ha, whereas at the ploughing – 7.88–10.10 t/ha, and at the shallow subsurface one – 8.11–8.85 t/ha. The minimal-typical interval was 4.11–4.75 t/ha, 3.81–5.09 t/ha and 3.72–4.43 t/ha correspondingly. The variability of productivity relative to the average value at the subsurface loosening was below 30 per cent, whereas at the ploughing and surface treatment it exceeded 30 per cent (Fig. 3).

The spring barley productivity in comparison with 1980–1990 reduced on the average by 0.66 t/ha or, by 23.8 per cent, and was the highest at the deep subsurface loosening. Within the entire period of explorations the average barley productivity was the highest at the systematic subsurface loosening (3.75 t/ha), then at the surface treatment it lowered by 0.06 t/ha, while at the ploughing – by 0.13 t/ha (HIP_{05}=0.11 t/ha). The maximal-typical barley productivity was the highest at the subsurface loosening – 4.55–5.05 t/ha.

Both at the ploughing and shallow subsurface loosening, the typical productivity was reduced by 1.05–1.12 times. Independent of the cultivating method, the variability of the barley productivity was below by 30 per cent, whereas exceeded 30 per cent in control without fertilizers. The trends of the productivity change were of the descending nature with the reliable difference (according to R^2 index) concerning the cultivating methods (Fig. 4).

The matter of the excessive heat resource effective use is connected to the mineral and organic fertilizers treatment; also taking into account the different cultivating methods at the crop rotations of various types (see Table 1). At the grass-including crop rotation and treatment with 6 t/ha of manure and average dose of fertilizers the average winter wheat productivity independent of the cultivating method was 4.69 t/ha, the spring barley – 4.54 t/ha, and during 2001–2010 at replacement of manure with side-line products – 4.21 and 3.37 t/ha respectively, what is by 0.48 and 1.17 t/ha less. At the five-plot pea-including crop rotation the average winter wheat productivity was reduced by 1.09 t/ha or, by 20 per cent during 2001-2010. At the grass-including crop rotation, on the contrary, the considerable reduction in the productivity was observed at ploughing (–0.59 t/ha), whereas the grain productivity remained higher at deep cultivating. The corn productivity at the crop rotation with the perennial grass grew on the average at various cultivating methods by 1.71 t/ha, and at the pea-including crop rotation – by 1.95 t/ha. A larger increase in the grain productivity has been noted at the subsurface (+2.09 and +2.0 t/ha) and surface (+1.97 and 2.37 t/ha) loosening subject to the crop rotation type.

The spring barley productivity, as compared to 1980-1990, was reduced on the average on 0.66 t/ha or, by 23.8 per cent, and the highest was at the deep subsurface cultivating. The return from the applied fertilizers proved to be higher in 1982–1992 by 123 per cent independent of the cultivating method. The barley productivity was reduced at ploughing (–1.57 t/ha), and the most considerable drop was at subsurface and surface loosening: -1.60 and -1.60 t/ha respectively.

The cereal crops productivity at the organic-mineral fertilizer and crop rotation with the perennial grasses never changed (5.09 and 5.13 t/ha), but at the pea-including crop rotation it reliably grew up at various cultivating methods. At the manure treatment against the background of the mineral fertilizers the addition of grains was 1.14 and 1.27 t/ha on the average, while at replacement of manure with side-line products – 1.43 and 1.47 t/ha, depending on the type of crop rotation. The increase of the grain owing to introduced fertilizers in 2001–2010, as compared to 1976–1998 grew by 1.25 and 1.16 times respectively to the crop rotation either with grasses, or pea. Depending on the cultivating method the return from the organic-mineral fertilizers treatment (6 t/ha of manure) in the form of the increase of grains was higher at ploughing and subsurface loosening: +1.38 and 1.14 t/ha and 1.62 and 1.40 t/ha respectively to the crop rotation either with grasses, or pea. At the replacement of manure with side-line products (6–7 t/ha) the addition of the grain owing to applied fertilizers proved to be higher at ploughing for the crop rotation with grasses, and for the crop rotation with pea was unchanged independent of cultivation method (see the Table).

The period of 2011–2013 was critical according to the indices of temperature conditions: the annual sum of effective temperatures (> 5 ºC) exceeded standard by +395 ºC, during the warm period of year – by +280 ºC, and during the summer period – by +146 ºC. As for the sum of efficient temperatures: during a year in whole – by +415 ºC, during the warm period of year – by +289 ºC, during the summer period – by +150 ºC compared to the standard. The average-daily air temperature since June till July (phase the earing-grain pouring-ripening of both winter and spring cereals) exceeded standard by +1,5–1.7ºC (the standard is +20.1 ºC), the sum of effective temperatures (> 5 ºC) was above standard by +125 ºC, and the sum of active ones – by +200 ºC. That creates conditions, when during the critical growing phases both winter and spring cereals fall into “the windburn” decreasing their productivity.

According to the data [4, 5], by 2025 the average daily air temperature during the vegetal period in the Central Left-Bank Ukrainian Forest-Steppe must grow to +17.74 ºC, while by the forecast scenario [4] – to +18.14 °C (until 2050), but in 2011–2013 the average-daily air temperature in April-October appeared to be +18.5 ºC, what is by +2.48 ºC higher than the standard; in the summer period – +21.2 ºC, which exceeds the standard by +1.7 ºC, and the annual average-daily temperature increased by +2.05 ºC, while the standard is by +7.22 ºC. Following to the temperature indices coinciding with the scenario by A.G. Tarariko [5] during 1982–2012 and the forecasted scenario for 2025–2050 [4], it is similar to the Central Steppe.

CONCLUSIONS

1. The excessive heat resource observed during 2001-2013 in the Central Left-Bank Ukrainian Forest-Steppe anticipates in raising tempos the forecast scenarios of the climatic change until 2025 and requires the adaptive agriculture system introduction. First of all, this is the implementation of the steppe agriculture methods: depth-varying chernozems cultivation, soil protective by its nature, subject to the precise following of the postharvest cultivation technological operations in the summer-autumn period with the simultaneous autumnal basic treatment with both organic and mineral fertilizers; also denying of the basic dose of the mineral fertilizers during spring cultivation, as it is common for the contemporary agriculture, and also the use of green-manured fallows in the structure of planted areas.

2. In the contemporary conditions of the climatic change, in particular, an increase in temperature to the forecasted rate of 2025 in the Central Left-Bank Ukrainian Forest-Steppe favorably affects an increase in the productivity of the existing corn hybrids, whereas the productivity of winter wheat and barley has the descending general trend during entire period of studies through an increase in the temperature of air to the critical values in the period of grain earing and pouring. The excessive heat resource is effectively used by the contemporary corn hybrids of middle- and late-ripening groups, for which in the “windburn” period of spring and winter cultures the optimal conditions of soil and air moisture supply are provided contributing to increase in their productivity.

3. The analysis of the cereal crops productivity during 2011–2013 acquires the special importance depending on the crop rotation type, fertilizer and cultivating method. The productivity of winter wheat in the pea-including crop rotation at systematic ploughing is 4.67–5.15 t/ha, at surface cultivating interrupted by ploughing for sugar beet – 5.0–5.05 t/ha, at the permanent surface cultivating for all plants in crop rotation – 4.50–4.64 t/ha. In the crop rotation with the perennial grass the winter wheat productivity appeared to be the highest at surface cultivating – 4,89–4.95 t/ha, and at subsurface loosening and ploughing the wheat productivity was 4.73 and 4.50 t/ha, what is reliably lower ($HIP_{0.05}$ = 0.25) relative to systematic ploughing.

4. The corn productivity in the crop rotation with pea and grass was highest at ploughing: 9.45–10.0 and 11.3 t/ha respectively. At the subsurface loosening the corn productivity was reduced by 1.03 and 1.7 t/ha subject to the crop rotation types, and after surface cultivating it decreased to 8.53–8.85 t/ha. The cereal crops productivity proved to be the highest on systematic ploughing both at the crop rotations with the grass and pea: 6.45 and 8.19 t/ha respectively. At the subsurface loosening the grain crops productivity had a tendency towards decrease, but remained within the limits of the reliable values: productivity decreased by 0.76 and 0.57 t/ha or 9.3 and 8.8 per cent; at the surface cultivating – to 0.86 and 0.92 t/ha or to 10.5 and 14.3 per cent (reliable value).

Вплив зміни клімату на врожайність зернових культур за різного обробітку ґрунту в агроценозах зерно-бурякових сівозмін лівобережного Лісостепу України

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Мета. Оцінити вплив сучасних змін клімату на формування продуктивності зернових культур (пшениці озимої та кукурудзи) залежно від системи адаптаційних заходів (удобрення, обробітку, типу сівозмін) в агроценозах центрального лівобережного Лісостепу України. **Методи.** На основі довгострокових (35−40 років) багаторічних досліджень у багатофакторному стаціонарному досліді проаналізовано динаміку врожайності зернових культур залежно від обробітку ґрунту, типу сівозміни та удобрення, а також змодельовано вплив метеорологічних показників на характер зміни трендів врожайності зернових культур у часі. **Результати.** Ефективне використання надлишкового теплового ресурсу пов’язане із внесенням мінеральних та органічних добрив за різних способів обробітку ґрунту в сівозмінах різного типу. У сівозміні з травами за внесення 6 т/га гною та середньої дози добрив врожайність озимої пшениці незалежно від способу обробітку становила 4,69 т/га, ячменю ярого – 4,54 т/га, а за 2001−2010 роки при заміні гною на побічну продукцію – відповідно 4,21 і 3,37 т/га, що менше на 0,48 і 1,17 т/га відповідно. Врожайність ячменю ярого порівняно з періодом, коли вносили гній, знизилася у середньому на 0,66 або на 23,8 %, а найвищою вона лишалася за глибокого безполицевого обробітку. Віддача від внесених добрив була вищою на 123 % незалежно від способів обробітку. У п’ятипільній сівозміні з горохом середня врожайність пшениці озимої за 2001−2010 роки знизилася на 1,09 т/га або на 20 %. Найістотніше падіння врожайності зерна було за безполицевого та поверхневого обробітків: −1,57−1,60 і 1,60 т/га відповідно. У сівозміні з травами, навпаки, суттєвіше зниження врожайності виявилося за оранки (−0,59 т/га), а вищою врожайність зерна лишилася за глибоких обробітків. Врожайність кукурудзи в сівозміні з багаторічними травами зросла в середньому по обробітках на 1,71 т/га, а в сівозміні з горохом – на 1,95 т/га. **Висновки.** Надлишковий тепловий ресурс у період 2001−2013 рр. в умовах лівобережної частини Лісостепової зони України за темпами наростання випереджає прогнозні сценарії зміни клімату до 2025 року та потребує запровадження системи адаптивного землеробства: застосування різноглибинного обробітку чорноземів з чітким дотриманням технологічних операцій післяжнивного обробітку в літньо-осінній період з одночасним основним осіннім внесенням органічних і мінеральних добрив, що робить недоцільним внесення основної дози мінеральних добрив під весняну культивацію, а також використання сидеральних парів у структурі посівних площ. За сучасних умов зміна клімату, зокрема, підвищення температури в центральній частині Лівобережного Лісостепу України позитивно впливає на зростання врожайності існуючих на сьогодні гібридів кукурудзи, тоді як для врожайності озимої пшениці і ячменю спостерігається загальний спадний тренд за весь період досліджень через підвищення температури повітря до критичних значень у період колосіння і наливу зерна. Надлишковий ресурс тепла ефективно використовують сучасні гібриди кукурудзи середньо- і пізньостиглої групи, для яких у період “запалу” ярих і озимих культур створюються умови оптимального ґрунтового і атмосферного вологозабезпечення, що сприяє зростанню їхньої врожайності.

Ключові слова: зернові культури, озима пшениця, тепловий ресурс, безполицевий обробіток, зерно-просапна сівозміна, органічні добрива.

Влияние изменения климата на урожайность зерновых культур при разных способах обработки почвы в агроценозах зерно-свекольных севооборотов левобережной Лесостепи Украины

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Цель. Оценить влияние современных изменений климата на формирование продуктивности посевов зерновых культур (пшеницы озимой и кукурузы) в зависимости от системы адаптационных мероприятий (удобрение, обработка, тип севооборота) в агроценозах центральной левобережной Лесостепи Украины. **Методы.** На основе долгосрочных (35−40 лет) многолетних исследований в многофакторном стационарном полевом опыте проанализирована динамика урожайности зерновых культур в зависимости от возделывания почвы, типа севооборота и удобрения и смоделировано влияние метеорологических показателей на характер изменения трендов урожайности зерновых культур во времени. **Результаты.** Эффективное использование избыточного теплового ресурса связано с внесением минеральных и органических удобрений при разных способах возделывания почвы в севооборотах разного типа. В севообороте с многолетними травами при внесении 6 т/га навоза и средней дозы удобрений урожайность озимой пшеницы независимо от способа обработки почвы составляла 4,69 т/га, ячменя – 4,54 т/га, а за 2001–2010 годы при замене навоза на побочную продукцию соответственно – 4,21 и 3,37 т/га, что меньше на 0,48 и 1,17 т/га. Урожайность ярового ячменя в сравнении с периодом внесения навоза снизилась в среднем на 0,66 т/га или на 23,8 %, а наивысшей осталась при глубоком безотвальном рыхлении почвы. Отдача от внесенных удобрений оказалась выше на 123 % независимо от способа обработки почвы. В пятипольном севообороте с горохом средняя урожайность пшеницы озимой за 2001–2010 годы уменьшилась на 1,09 т/га или на 20 %. Наиболее существенное снижение урожайности зерна отмечено при безотвальном и поверхностном рыхлении почв. В севообороте с многолетними травами, напротив, более существенное падение урожайности было при вспашке (–0,59 т/га). Урожайность кукурузы в севообороте с многолетними травами выросла в среднем по вариантам обработки почвы на 1,71 т/га, а в севообороте с горохом – на 1,95 т/га. **Выводы.** Избыточный тепловой ресурс в период 2001–2013 гг. в условиях левобережной части Лесостепной зоны Украины по темпам нарастания опережает прогнозные сценарии изменения климата до 2025 года и нуждается во внедрении системы адаптивного земледелия: применении разноглубинной обработки черноземов с четким соблюдением технологических операций послеуборочного возделывания в летне-осенний период с одновременным основным осенним внесением органических и минеральных удобрений и без внесения основной дозы минеральных удобрений под весеннюю культивацию, а также в использовании сидеральних паров в структуре посевных площадей. В современных условиях изменение климата, в частности, повышение температуры в центральной части левобережной Лесостепи Украины положительно влияет на рост урожайности существующих гибридов кукурузы, тогда как для урожайности озимой пшеницы и ячменя наблюдается нисходящий общий тренд за весь период исследований из-за повышения температуры воздуха до критических значений в период колошения и налива зерна. Избыточный ресурс тепла эффективно используют современные гибриды кукурузы средне- и позднеспелой группы, для которых в период "запала" ярых и озимых колосовых культур создаются условия оптимального почвенного и атмосферного влагообеспечения, что способствует возрастанию их урожайности.

Ключевые слова: зерновые культуры, озимая пшеница, тепловой ресурс, безотвальное рыхление, зерно-просапной севооборот, органические удобрения.

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