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Factors of stabilization of production of grain of winter wheat in Right-bank forest-steppe region

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The purpose. To justify risks and opportunities of stable production of grain of winter wheat in state-of-the-art agrophytocenosis of Right-bank forest-steppe region. **Methods.** Analysis, synthesis, generalization, field experiment. **Results.** Influence of modern techniques upon productivity and quality of grain of winter wheat is probed at late seeding emergence. Expediency of use of postharvest plant residues in conditions of limited application of organic fertilizers is proved. **Conclusions.** Later seeding emergence of winter wheat in 70% of events is imminent after late predecessors because of excessively droughty and rainy September, and after early predecessors such probability makes 50%. Application of no-till-technique enables to decrease essentially term between sowing and sprouts and to prolong autumn vegetation. Optimization of existing systems of mineral nutrition with the use of crop residues, bacterization of seeds and microfertilizers, high quality grades positively influences productivity of grain and its quality.
Key words: *winter wheat, rainfall, nitrogen-fixing and phosphorus-mobilizing bacteria, fertilizers, grade.*

Seeding terms of winter wheat are an important element of its cultivation technology. Their significance greatly increases due to complications in modern agrocenoses caused by the changes of the anthropogenic and natural origin, which are well observed during the last decade [1].

It is known that the seeding terms are divided into early ones, i.e. those that cause certain risks of yield reduction caused by the excessive growth of the leaf and stem mass during the period when the autumn vegetation is over; optimal ones, i.e. those that in the vast majority of cases produce the highest yield under other equal technological conditions, and later ones, i.e. those that cause the risks of the yield decrease due to insufficient development of plants before overwintering period.

It is established that in terms of obtaining high yields the optimum phase is the phase of plant development, when it forms a tillering node, 2-3 productive shoots, a secondary root system and has accumulated enough sugar for the period when the autumn vegetation is over, which corresponds to the phase of the beginning of autumn tillering. For such development, plants have to take 240-260 ^{0}C of active temperatures, which corresponds to 35-38 days of vegetation in the region [2-4].

If early sowing with all its benefits and risks is a conscious and free choice, then the late sowing, where risks dominate the benefits, is forced and requires additional measures aimed to weaken its negative effects. One of them is an increase in the initial rates of nitrogen fertilizers, however, they do not always guarantee the desired result since even the increased mineral nutrition background is not able to compensate the depressive effect of lower temperatures on plants, which occurs in October and November. In addition, the increase in the rates of nitrogen fertilizers in years of early vegetation termination cannot be used sufficiently by plants, which leads to unproductive losses of nitrate forms in the autumn-winter period. In this regard, there is a need to search for other forms of nitrogen fertilizers, which make it possible to prevent these losses. Therefore, under the condition of late emergence, the maximum approximation of mobile compounds of nitrogen and phosphorus to the young seedlings is of great importance, which can be achieved by presowing seed treatment with nitrogen-fixing and phosphorus-mobilizing bacteria [5-7].

It is proved that organo-mineral system is the most effective system of winter wheat fertilization under the conditions of reduction of humus content in the soil [8]. Due to the decrease in the amount of organic fertilizers of animal origin, the relevance of the use of post-harvesting residues for mineral plant nutrition is sharply increasing.

Under conditions of the global climate change, further intensification of grain production should be based on the application of adaptive farming systems that would be tolerant to these changes as much as possible and guarantee sustainable grain production [9, 10]. The most adapted component of agrophytocenoses is a variety that is created under the effect of a specific ecosystem, having the features that are most inherent in this system [11]. In the structure of the yield elements, the specific share of the variety is about 50% and it will continue to grow [12]. However, under the pressure of market interests and conditions, this factor is ignored by agribusiness more often, and along with the yield increase in the favorable years causes its sharp decline in unfavorable ones. At the same time, recommended domestic varieties for every agro-climatic zone are more tolerant to such changes [13].

The effects of late emergence can be significantly reduced due to optimization of the system of mineral nutrition as well as application of trace elements during the period of winter wheat growth [14].

Meanwhile, practical experience and research data on the ways of grain production stabilization under current conditions of natural and anthropogenic changes in the agrocenoses of the right-bank Forest-Steppe are insufficient. The issue of the effect of No-till-technology on the optimization of the soil moisture supply under the increased risks of late emergence remains a controversial one. That is why the search for the ways of ensuring sustainable grain production is growing in importance.

Research results. The analysis of multi-year air temperature indicators shows that over the last decade in most years the active autumn vegetation is over at the end of the first decade of November. It means that under conditions of the region the sprouts must germinate no later than October 10-12 to start the tillering phase.

Our studies have shown that the seeding terms (except for the late ones) and the actual emergence of sprouts are far from proportional dependence due to the lack of the optimal ratio of moisture and heat.

Even when wheat was grown after the predecessor crops that were harvested early, early and optimal seeding terms ensured proper crop emergence every five of ten years. The remaining five years with a severe September drought made germination possible only after rainfalls, as a rule, in the first decade of October, which caused a decrease in the autumn period of plant development (Fig. 1). If in September the limiting factor was moist, then in October it was heat, the number of active values of which gradually decreased. During the last ten years, every five years October was 1-3 ^{0}C warmer than a long-term norm, and the years when the October colds changed the September drought were observed four times in ten years, while during the last five years, three of them were characterized by this phenomenon, which is extremely unfavorable for plant growth and development (Fig. 2).

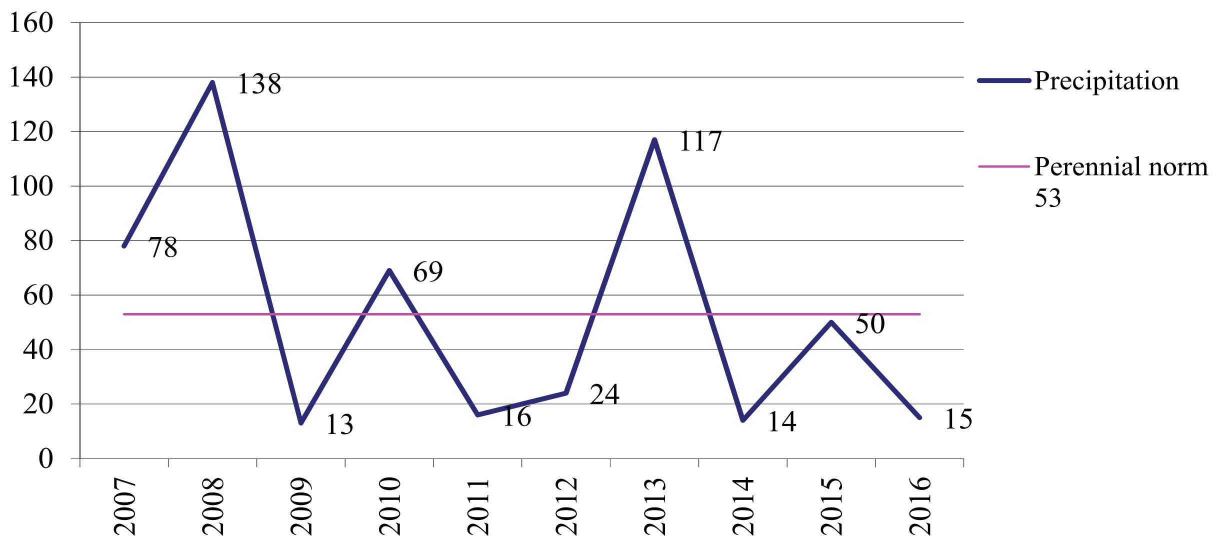

Fig. 1 Dynamics of September precipitations

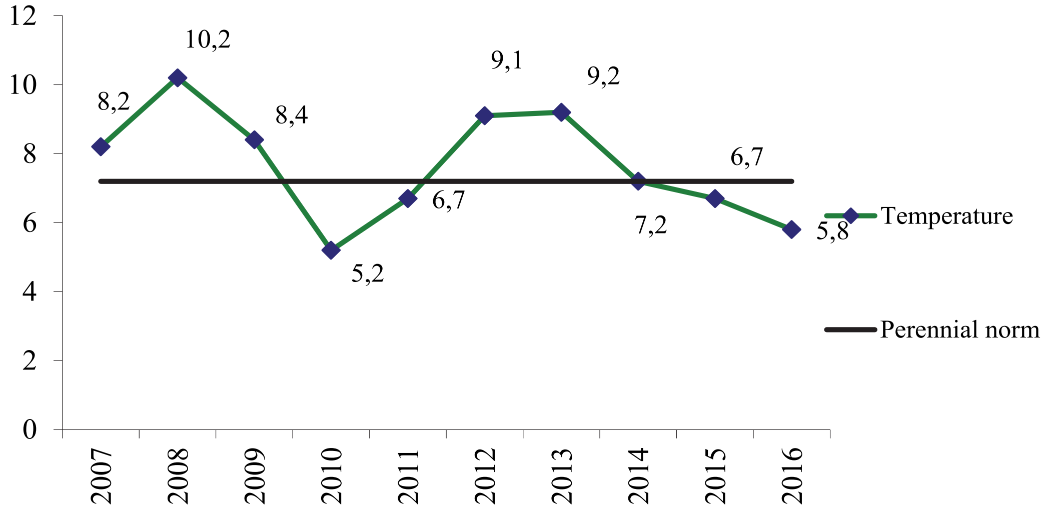

Fig. 2. Dynamics of the average daily air temperatures in October

When wheat is grown after soybean and other late predecessor crops, the timely emergence of sprouts is impossible both in dry and rainy September. In the first case, it occurs due to excessive drying of the sowing and arable soil layer, in the second case it is caused by the delay in harvesting of predecessor crops. Under drought conditions, crop emergence will be late no matter when the crop is sown, while under conditions of excessive moisture, the early and optimal sowing terms will be technically impossible, which will cause a similar result.

Therefore, when wheat is grown even after early soybean varieties, early (by September 15) and optimal sowing terms, which provide appropriate dates for crop emergence, have been observed only three of ten years under conditions of the region during the last decade. In the remaining seven years, they are inevitably regarded as late with all the negative effects of both dry and excessively moist September. At the same time, it should be noted that 1.8 ^{0}C warmer weather in the first half of November, significantly weakens these effects on the state of crop overwintering and yield formation, which allows somewhat to postpone permissible sowing terms to the later ones. However, the risks of late emergence still remain.

Thus, ensuring of the correspondence between the optimal sowing terms and crop emergence is based on the optimization of the soil moisture supply in September. This will enable to maximize the use of the October heat for the earlier crop emergence. To achieve the prolongation of the autumn vegetation period by reducing the term between wheat sowing and emergence can be achieved by the implementation of the science-based crop rotations, which are formed according to the principle of fruit succession. However, in the years of severe August and September drought, they do not solve the problems sufficiently, and when wheat is grown after late predecessor crops the timely crop emergence becomes even more problematic in 70% of cases.

Under such conditions, it is possible to reduce the period between the sowing and emergence by accumulation of the August and September moisture in the soil due to application of zero cultivation (Table 1).

Table 1. Duration of the sowing period – full emergence under different technologies of winter wheat cultivation (2011-2016)

Growing technology	Supply of productive moisture in the arable layer of soil at the beginning of optimum sowing terms, mm	Average daily temperature of the sowing layer in October, t ^{0}C	Duration of the period between the sowing and emergence, days	Condition of plant development at the time of autumn vegetation termination
Conventional	9.3	9.1	18 – 21	2-3d leaf
No-till	15.4	10.9	12 – 14	Beginning of tillering

The temperature of the soil in October also affect the duration of the pre-emergence period. Studies have shown that this heat deficit, which gradually increases in all conditions, is especially relevant for wheat emergence if it is preceded by a September moisture deficiency. These parameters can be significantly optimized by the zero soil tillage (Table 1). In the sunny hours, the surface of the open ground warms up better than the mulched with plant residues, however, at night it is cooled more quickly, while due to No-till-technology the sowing layer retains heat that is emitted by warm lower layers. In addition, in the years with rainy October, the number of days with solar insolation is 6-7, or only 19-22% under the region conditions. Our observations have shown that under such conditions the benefits of no-till are intensified.

It was noted that the use of post-harvesting plant residues causes the increase in grain yield by 0.31 t/ha and by this indicator it is almost as efficient as the increase in the rate of mineral fertilizers from $N_{90}P_{40}K_{60}$ to $N_{120}P_{50}K_{75}$ (Table 2).

Table 2. The effect of the fertilization system on the yield and quality of winter wheat grain (2011-2013)

Fertilization system	Grain yield, t/ha	Protein content, %
Control (no fertilizer)	3.07	9.8
Co-peoducts – Background	3.38	10.0
Background + $N_{90}P_{40}K_{60}$	5,47	12.0
Background + $N_{120}P_{50}K_{75}$	5.86	12.3
Background + seed bacterization	3.87	10.6
Background + $N_{90}P_{40}K_{60}$+ seed bacterization	6.02	12.9
Background + $N_{120}P_{50}K_{75}$ + seed bacterization	6.41	13.2
Background + seed bacterialization s + microfertilizer Rostock	4.43	11.2
Background + $N_{90}P_{40}K_{60}$+ seed bacterization + microfertilizer Rostock	6.70	14.2
Background + $N_{120}P_{50}K_{75}$ + seed bacterization + microfertilizer Rostock	7.11	14.4
LSD_{05}, t/ha	0.15	

Seed bacterization with nitrogen fixing and phosphorus-mobilizing bacteria contributed to the growth of grain yield by 0.49 t/ha.

Double foliar nutrition of winter wheat by microfertilizer Rostok caused an increase in grain yield by 0.56 t/ha. The total positive effect of post-harvesting residues, seed bacterization and microfertilizer Rostok resulted in the yield increase by 1.36 t/ha or 44.2%. At the same time, its quality indicators significantly improved. Thus, under the effect of the use of post-harvesting residues for the soil needs, protein content in grain increased from 9.8 to 10.0, seed bacterization from 10.0 to 10.6, microfertilizer Rostok from 10.6 to 11.2%.

Table 3. The yield of winter wheat grain depending on the fertilizer and varieties (2014-2016), t/ha

Fertilization system	Grain yield, t/ha		
	Varieties		
	Economca	Pylypivka	Darunok Podillya
No fertilizer	5.15	4.79	5.38
$P_{50}K_{75}$+ Ammonium nitrate N_{150} before seeding	6.22	5,90	6,79
P_{50} K_{75}+ carbamide N_{150} before seeding	7.10	6.60	7.37
P_{50} K_{75}+CAM N_{150} before seeding	6.55	6.35	7.34
$P_{50}K_{75}$+ Ammonium nitrate: N_{30} before seeding + $N_{90\ III}$ + $N_{30\ IV}$ stage of organogenesis	6.71	6.27	7.56

$P_{50}K_{75}$ + carbamide: N_{30} before sowing + $N_{90\,III}$ + $N_{30\,IV}$ stage of organogenesis	7.51	6.76	7.68
P_{50} K_{75}+CAM: N_{30} before seeding +N_{90III} +$N_{30\,IV}$ stage of organogenesis	7.01	6.49	7.54
P_{50} K_{75}+ Ammonium nitrate: N_{30} before seeding + $N_{90\,III}$+N_{30} + Mono Manganese $_{IV}$ + Mono Copper + Mono Magnesium $_{VIII}$ stage of organogenesis	7.34	6.45	7.63
P_{50} K_{75} + carbamide: N_{30} before sowing + N_{90III} + N_{30} + Mono Manganese$_{IV}$ + Mono Copper + Mono Magnesium $_{VIII}$ stage of organogenesis	7.77	7.33	8.43
P_{50} K_{75} + CAS: N_{30} before sowing $N_{90\,III}$ N_{30} + Mono Manganese $_{IV}$ + Mono Copper and Mono Magnesium $_{VIII}$ stage of organogenesis	7.58	6.91	7.91
LSD_{05}, t/ha		0.17	

It was established that all varieties responded equally positively to the system of fertilization (Table 3). Variety Pylypivka of the southern ecotype appeared to be the most sensitive one to the lack of fertilizers, while Darunok Podillya of the Forest-Steppe ecotype was the most tolerant one. However, this variety was the most productive when applying fertilizers providing a yield increase of 1.41 t/ha, while varieties Pylypivka and Economka yielded 1.07 and 1.11 t/ha, respectively.

Substitution of ammonium nitrate into amid nitrogen when applied before sowing caused an increase in grain yield from 0.58 in variety of Darunok Podillya to 0.7 and 0.88 in varieties Pylypivka and Economka. Application of carbamide-ammonia mixture before sowing appeared to be more effective compared to ammonium nitrate in all varieties, however, the highest yield increase caused by such replacement (0.55 t/ha) was observed in variety Darunok Podillya, while the lowest one (0.33 t/ha) was observed in variety Economka.

Compared to pre-sowing application of carbsmide the use of CAM apperared to be less effective in variety Pylypivka and much less effective (by 0.55 t/ha) in Economka variety and was almost equivalent to that one in Darunok of Podillya.

Multiple application of ammonium nitrate in all varieties was more effective than its single dose during sowing. Darunok of Podillya appeared to be the most sensitive to such nitrogen distribution during vegetation periods having provided an increase in grain yield of 0.77 t/ha, and Pylypivka variety was the least sensitive one (0.37 t/ha).

A similar distribution of carbamide by the vegetation periods compared to its single pre-sowing dose was less efficient than ammonium nitrate in Pylypivka (+0.16 t/ha) and Darunok of Podillya (+0.31 t/ha); Economka appeared to be more sensitive with the increase in grain yield of 0.41 t/ha. This variety also had the best response to multiple application of CAS with the yield increase of 0.45 t/ha.

Application of foliar nutrition with manganese in the fourth stage of organogenesis and copper and magnesium in the eighth stages in all forms of nitrogen under multiple application provided a yield increase in all varieties. On the background of ammonium nitrate it was as follows: 0.63 t/ha in Economka variety, 0.18 in Pylypivka, 0.07 t/ha in Darunok of Podillya; on the background of carbamide it was 0.26, 0.57 and 0.75 t/ha respectively; on the background of CAS it was 0.57, 0.42 and 0.37 t/ha, respectively. The highest grain yield of 8.43 t/ha was provided by Darunok of Podillya under multiple application of carbamide, copper, manganese and magnesium. This indicator was lower by 0.66 t/ha in Economka variety and by 1.1 t/ha Pylypivka variety of the southern ecotype. However, it should be noted that this variety was the most resistant one to severe summer drought of 2015. Thus, in June and July precipitation equaled to 44.8 mm while the long-term norm is 173 mm, or 25% of the norm.

Conclusions.

When winter wheat is cultivated after early predecessor crops, the risk of later sowing in the years with excessively rainy September is observed every three years, in the years of the August and September drought it occurs every four of ten years, regardless of the calendar seeding terms. When cultivated after late predecessor crops, late emergence occurs every seven of ten years. At the same time, it is inevitable because of excessively humid September due to the delay in harvesting of the predecessor crop as well as an arid month due to the lack of soil moisture. An autumn vegetation period in the arid years can be prolonged due to reduction of the term between seeding and emergence through No-till-technology. Negative effects of late emergence can be mitigated by the pre-sowing seed treatment with nitrogen-fixing and phosphorus-inhibiting bacteria as well as optimization of the nutrition system. The growth of yields is positively influenced by the use of post-harvesting residues for the needs of the soil, optimization of the forms and terms of applying nitrogen fertilizers, formation of the variety composition of the certain ecotype taking into account the soil and climatic conditions of the region.

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