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Morphophysiological features of formation of productivity of summer wheat in conditions of climate fluctuation

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The purpose. To determine morpho-physiological features of formation of productivity of summer wheat at techniques of different intensity in conditions of climate fluctuation. **Methods**. Field, laboratory researches, mathematical-statistic analysis. Researches went into: monitoring of state of plants in ontogenesis, determination of duration and conditions of transiting of organogenesis, dynamics of density plant stand and extents of its implementation, reduction of productive caulises, amounts of flowers in an ear, values of potential of an ear, formation of potential yield and extents of its implementation actually depending on weather environment and elements of technique of cultivation. **Results.** In 2011 – 2015 they had studied features of formation of separate elements of productivity of summer wheat at techniques of growing of different intensity. Relative analysis was carried out of weather environment on stages of organogenesis and formation of elements of productivity of summer wheat within congenial and unfavorable on weather environment for implementation of potential of productivity. Periods of the greatest reduction of flowers, density of plant stand, size of losses and implementation of potential in concrete weather environment were fixed. Dependence of these indexes on techniques of cultivation and weather environment was specified. Potential yield and extent of its implementation in actual was calculated. **Conclusions**. The highest productivity of agrophytocenosis of summer wheat — 7,87 t/ hectare — was gained in 2015 at high-intensity technique of cultivation which has ensured density of plant stand 550 p./m2 and productivity of an ear 1,5 g. Level of implementation of potential yield at IX stage of organogenesis in actual made 54% at productive plant stand of 54% and 38% of the preserved flowers for the period from V to XII stage of organogenesis. It is fixed that due to application of intensive techniques of cultivation it was possible to fractionally compensate negative influence of weather environment on formation of separate elements of productivity.

Key words: *stages of organogenesis, flowers, ear, density of plant stand, reduction, technique, weather environment.*

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Climate change has been taking place on the planet in recent decades. Under their influence, the climate of Ukraine changed as well and characterized by a tendency to warming, accompanied by a change of temperature regime and humidity, an increase in the frequency of climate anomalies. The intense climate warming in Ukraine can be clearly seen from 1988-1989, and in the last decade of the XX century have been the warmest for 100 years of meteorological observations. The average annual air temperature in Ukraine for the last 20 years has increased by 0.7-0.9 °C. In the Forest-steppe zone, in the region of activity of the NSC "Institute of Agriculture of the NAAS", during the period 1999-2018 the average air temperature exceeded the average long-term values by 0.3-2.7 °C.

In Ukraine, agriculture is largely dependent on weather and climate conditions and their fluctuations.

According to long-term observations of scientists of the NSC "Institute of Agriculture of the NAAS" and the network of research institutions, the influence of weather conditions on the formation of grain productivity in modern intensive cultivation technologies is 20-30%. In simplified versions of technology, their share is increased to 40%. In years with extreme weather conditions the influence of the natural factor on the productivity of crops increases to 60-70%, and in some years it can completely decide the quantity and quality of the future crop [1,2].

According to world experts, the impact of climate change on agricultural production will only increase in the future. In particular, it is expected that the air temperature will continue to increase, which will be followed by alternation of dry periods with periods of normal humidity. It is known that increasing the average annual temperature by 1 ° C leads to an increase in the duration of the growing season by 10 days and an increase in its heat supply [3-5].

Global warming can significantly increase the opportunities of the agricultural sector of the economy due to weather and climatic conditions. But this is possible only in the case of a radical adaptation of agricultural production to new climatic conditions, synchronized with the pace of their change. Otherwise, climate warming threatens the instability of agricultural production. Adaptation will reduce the level of harmfulness of the factor, take advantage of all existing opportunities for this purpose, as well as foresee the development of appropriate response strategies [6,7].

For the development of adaptive technologies of spring wheat cultivation, which will be based on the rational use of soil and climatic resources, as well as to effectively use the genetic potential of varieties, it is necessary to establish the basic laws of formation of productivity of the crop and its individual components in ontogeny, depending on the weather conditions, biological potential of variety and growing technology elements.

The study of processes of formation and reduction of organs of productivity in ontogeny, their comparison with climatic factors of environment and conditions of cultivation is possible thanks to the use of morphophysiological method of analysis. Morphophysiological studies make it possible to evaluate the impact of technology as a whole and its individual components on the formation of crop productivity depending on weather conditions, find the most vulnerable periods in its ontogeny, and identify reserves for improving the productivity of a particular spring wheat variety [8].

Materials and methods of research. During 2011-2015 in the stationary long-term experience of the Department of Adaptive Intensive Technologies of Cereals and Corn of the National Science Center "Institute of Agriculture of NAAS" in the Research state farm “Chabany” conducted researches to study the morphophysiological features of the formation of spring wheat productivity of the variety “Struna Mironivska”. They included monitoring the plant condition in ontogeny, determining the duration and conditions of the stages of organogenesis [9], the dynamics of stem density and degree of its realization, the reduction of productive stems, the number of flowers in the ear, the size of the ear potential, the formation of potential yield and the degree of its realization depending on the weather and the elements of growing technology.

Morphophysiological studies were performed on growing technologies that differed in doses of mineral fertilizers on the background of ploughing of by-products of the precursor (soybean) and integrated plant protection, which included the use of protection of wheat crops from weeds, diseases and pests according to the economic threshold of their harmfulness. Fertilization scheme for spring wheat growing technologies: 1. (resource-saving technology) - P30K30N30 before sowing and N15 for fertilization at IV stage of organogenesis (s.o.); 2. (intensive) - P60K60N30 for sowing and N30 for fertilization on IV and N30 on VIII s.o.; 3. (high intensity) - P90K90N45 before sowing and N45 on IV and N45 on VIII s.o.; 4. (control) - without fertilizers. On variants of technologies 1, 2, 3 - the by-products of the precursor (soybean) are ploughed. Phosphorous and potassium fertilizers were applicated into the main soil tillage, nitrogen fertilizers were applied to the main stages of organogenesis according to Kuperman.

Results of the studies and their discussion. According to the results of the research, it was found that the formation of spring wheat crop was significantly influenced by the weather conditions of this crop's growing season. In general, the vegetation conditions of 2011 and 2012 were not extreme for realizing the productivity potential of spring wheat varieties, although they createed, at certain periods, deviations from normal crop growth and development.

The period from the first to the third stage of organogenesis in 2013, by the duration that corresponded to the average long-term indicators, was characterized by an increase in heat and complete absence of precipitation (Table 1). The sum of active temperatures above 10°C exceeded the long-term average by 130°C. The duration of IV and V stages of organogenesis was reduced to 4 days each and was marked by increased average daily air temperatures and rainfall, which was half the average annual values, which, to some extent, limited the number of laid ears in the cone of growth. The vegetation period from VI to VII stage in terms of duration and amount of rainfall was close to the average annual values. The coming into ear (stage VIII) lasted 4 days and took place in moderate rainfall and high daily average air temperatures.

Stage IX reduced to 2 days and passed under moderate temperature conditions and complete absence of precipitation. The formation of the grain (X stage of organogenesis) took place with a shortage of rainfall and increased daily average air temperatures. Grain filling lasted close to the average long-term values and occurred in the absence of rainfall (48% of normal) and hot weather (HTC of 0.52 at the rate of 1.08).

Weather conditions of the spring wheat vegetation period in 2014 were characterized by a certain contrast of temperature regime and uneven distribution of rainfall at same stages of organogenesis, but had no particular negative impact on the formation of crop productivity.

In 2015, the weather conditions of the growing season were characterized by a sufficient amount of heat and a deficit of rainfall. Thus, the period from I to III stage of organogenesis with a duration that is 1.4 times higher than the average long-term values, was characterized by increasing heat and deficit of rainfall, the amount of which was 54% of the norm. Subsequent stages IV and V of organogenesis differed little from the average long-term values both in terms of duration and amount of precipitation and the sum of active temperatures, and passed at the HTC close to the optimum. This had a positive effect on the number of spiked cones in the growth cone at stage IV. Spring wheat vegetation period duration from stage VI to stage VII was close to the average long-term values and was characterized by a lack of rainfall. Coming into ear (stage VIII) continued for 6 days and took place in the absence of rainfall and elevated daily average air temperatures. The next IX stage was characterized by a moderate temperature regime and no precipitation. Overall, the weather conditions for grain formation and filling in 2015 were favorable and had a positive impact on both the grains number in the ear and the mass of 1000 grains.

We analyzed the morphophysiological features of the formation of spring wheat productivity at the main stages of organogenesis in the years that differed most in weather conditions and were the most favorable (2015) and unfavorable (2013) for realizing the genetic potential of the crop.

An important component of the formation of high-yielding agrocenosis of spring wheat is the number of grains in the ear. This figure is determined by the number of flowers laid in the cone of growth and those that reach the XII stage of organogenesis.

According to the literature, it is known that the greatest potential for a variety grown under certain conditions, the number of flowers in the ear of spring wheat is

1. Duration of stages of spring wheat organogenesis depending on air temperature and rainfall during vegetation (2013, 2015 and 2011-2015 average)

Stages of organogenesis	Duration of stages, days			Rainfall, mm			The sum of active temperatures >10^{0}C			Hydrological thermic coefficient (HTC)		
	2013	2015	Average of many years	2013	2015	Average of many years	2013	2015 p.	Average of many years	2013	2015	Average of many years
I - III	18	25	18	0	16,8	31,2	342,5	244	213	0	0,69	1,46
IV - V	8	13	14	13,4	23,4	26,1	165,1	182	199	0,81	1,29	1,31
VI - VII	18	15	16	30,8	9	34,4	324,4	373	261	0,95	0,24	1,32
VIII-IX	6	11	10	11,2	0	30,6	128,3	241	196	0,87	-	1,56
X	12	10	10	0,6	6,6	12,5	254,9	200	201	0,02	0,33	0,62
XI–XII	34	39	33	36	42,4	74,4	691,8	825	689	0,52	0,51	1,08
I - XII	96	123	101	92	98,2	209,2	1907,0	1984	1759	0,48	0,49	1,19

laid at the V stage of ontogeny [10,11]. As a result of morphophysiological studies it was established that under agrometeorological conditions of the vegetation period of 2015, the total number of flowers planted in the central ears of spring wheat Struna Mironivska varied within 117-141 flowers, 70-83 of which were synchronously developed. In the ears of the first order were 96-123 flowers, 57-73 of which were synchronously developed (Table 2).

Due to the fact that in 2013 I - III stages of organogenesis of spring wheat were held under conditions of increasing heat and complete absence of precipitation, and the duration of IV and V stages of organogenesis, when the ear is laid in the cone of growth and flowers in the ears, decreased to 4 days each, characterized by high daily average air temperatures and deficiency of rainfall, the number of laid ears in the growth cone and flowers in the ear was much smaller. The total number of flowers in the central ear of spring wheat of the Struna Mironivska variety at the V stage of organogenesis varied within 90-113 pieces, 52-68 of which were synchronously developed. In the ear of the first order were 60-78 flowers, 35-38 of which were synchronously developed. That is, under unfavorable conditions, both the total number of flowers and synchronously developed in the central colossus decreased by 18-28% compared with the results of 2015. To a greater extent, this decrease was shown in the laying of flowers in the ear of the first order, where their total number decreased by 31-39%, and synchronously developed by 39-42%.

On average, in the years 2011-2015, 115-139 flowers were laid in the spikelets of spring wheat of the variety Struna Mironivska, 67-83 of which were synchronously developed, and for the first-order spikes, this indicator ranged between 89-116 and 48-67 pieces, respectively.

Our research found that fertilizing with resource-saving and intensive cultivation technologies improved plant nutrition, which led to an increase in the number of planted flowers in the ear of both orders.

This pattern has been maintained throughout the years of studies with different weather. Improving plant nutrition through fertilizer application has, to some extent, offset the negative impact of weather conditions on the formation of individual productivity elements [12].

2. Formation of wheat productivity elements of spring variety Struna Mironivska depending on growing conditions (2013, 2015 and average for 2011-2015)

N of variant of technology	Fertilizing	Number of productive stems in the XII stage, pcs / m^2	Stem loss from VI to XII stage		Number of flowers, grains in the central ear at the stage, pcs. /ear		Reduction of flowers, grains from V to XII stage,%	Realization of the potential crop in the actual relative to the IX stage, %	The share of productivity of the central ears in the formation of the crop %
			pcs / m^2	%	V	XII			
2011-2015									
1	$P_{30}K_{30}N_{30+15(II)}$	479	293	38	125	41	67	46	82
2	$P_{60}K_{60}N_{30+30(IV)+30(VIII)}$	504	406	45	130	46	64	41	83
3	$P_{90}K_{90}N_{45+45(IV)+45(VIII)}$	554	618	53	139	50	64	42	85
4	Without fertilizers - control	409	225	36	115	35	69	41	86
2013									
1	$P_{30}K_{30}N_{30+15(II)}$	570	90	14	95	35	63	42	53
2	$P_{60}K_{60}N_{30+30(IV)+30(VIII)}$	590	280	32	110	39	65	41	47
3	$P_{90}K_{90}N_{45+45(IV)+45(VIII)}$	620	200	24	113	44	61	40	47
4	Without fertilizers - control	475	35	7	90	31	66	42	59
2015									
1	$P_{30}K_{30}N_{30+15(II)}$	515	385	43	132	44	67	61	70
2	$P_{60}K_{60}N_{30+30(IV)+30(VIII)}$	530	400	43	134	49	65	60	71
3	$P_{90}K_{90}N_{45+45(IV)+45(VIII)}$	550	470	46	138	53	62	54	70
4	Without fertilizers - control	510	70	12	117	39	67	47	68

Notes. 1 Technology variant: 1-resource-saving technology, 2-intensive, 3-high-intensity, 4-control.2. On variants 1, 2, 3 - the by-products of the predecessor are ploughed

Much of the flowers planted in the V stage of ontogeny are reduced without reaching the XII stage. The reduction of flowers for this variety in the weather conditions of 2015 was 62-67% of their total number in the V stage for the central stems and 67-73% for the first-order stems, and was slightly different from the average data for 2011-2015 and was within 64- 70% and 67-74%, respectively.

The dependence of the loss of the number of flowers in the ears of both orders on the conditions of nutrition was established. A larger size of flower reduction was observed in the shortage of fertilizers without fertilizer (control).

On the basis of morphophysiological researches the main periods are determined in which a considerable part of the laid flowers of this variety were lost and their parameters are stated. According to their results, on the average for the years 2011-2015, 41-43% of the flowers planted at the V stage at the variety Struna Mironivska from V to VI stage are lost in the period from V to VI. From stage VI to IX, the reduction is 14-19% of all planted flowers. In the period from IX to XI stage the size of reduction was 2-9%, and from XI to XII - it decreased to 1-3%.

An important indicator in the formation of productivity is the number of fertile flowers at the IX stage of organogenesis The results of morphophysiological studies showed that their number at the IX stage in 2015 in the central ears depended on the doses of applied fertilizers and varied from 52 flowers in control to 53 for resource-saving technology. By increasing the fertilizer dose by two and three times with intensive technologies, the number of flowers increased to 54 and 57 pieces. In 2013, the number of fertile flowers at the stage IX in the central ear was determined by the weather conditions at the VIII and IX stages of organogenesis and their number laid at the previous stages and depended on the rates of fertilizers applied. Their number in the central ears was lower by 8-10 flowers for fertilizer technologies and by 13 flowers for control, compared to the results of studies in 2015.

In the end result, at the XII stage of organogenesis in 2015 (in the phase of full ripeness), the central ear contained 39-53 grains and 26-39 grains in the first order ear. Under the extreme conditions of 2013, the grains number of the ear was lower by 17-21% in the central ear and by 16-27% - in the ear of the first order compared to 2015. According to the variants of the cultivation technology, which included the application of fertilizers, owing to the improvement of the conditions of nutrition of the plants, the grains number of the ear and the number of spikelet in the ear increased. Insufficient nutrition on controls (without fertilizers) have led to a significant reduction in number of grains of the ear in different weather conditions.

Creating an optimal productive stem density is an important component of the formation of high-yielding spring wheat agrocenosis. According to our research, weather conditions significantly influenced the formation of spring wheat stalks. However, even in the most favorable weather conditions in 2015, the rainfall deficit to some extent limited the tillering of spring wheat. Stem density at stage IV of organogenesis ranged from 390-860 pcs / m with a tillering coefficient of 1.0-1.9. By stage VI, the total number of stems had increased to 580-1230 pieces / m , and the tillering ratio was 1.5-2.9. At this stage, the density of the total stem was at the control of 580 pieces / m^2. At the same time, the growing number of stems increased from 920 to 1230 pieces / m^2 by growing technologies with the introduction of increasing fertilizer rates. On average, during the years of research, the value of the stem density varied within 634-1172 units / m^2 depending on the growing technology. In the drier 2013, the stem density was lower during this period and ranged from 510 to 870 pcs / m depending on the fertilizer application rates. The total stem density was 510 pc / m^2 at the control. The use of fertilizers in growing technologies has increased the density of the stem from 660 to 870 pieces / m^2, depending on their application rates.

From VI to IX stage of organogenesis there was a significant reduction of the stems nunber. Under the weather conditions in 2015, 10-54% of the stems from their density in the sixth stage were lost during this period. From IX to XII stage the size of reduction was smaller and ranged from 2-12%. In 2013, up to 31% of stems from their density in stage VI were lost during this period. From IX to XII stage the size of reduction was in the range of 2-7%. In the period from VI to XII stage of stem loss was 7-32%. On average, in 2011-2015, from VI to IX stage, 38% of stems were lost from the number of them at the VI stage of organogenesis, while 36% were in control. With intensive technologies, the value of stems number reduction was 45-53%.

The number of productive stems at the XII stage of organogenesis in 2015 was close to the average perennial values and amounted to 510-580 pieces / m^2.

Under the weather conditions in 2013, there was a greater contrast between the density of the stem and the rates of fertilizers applied by different growing technologies. Until the XII stage of organogenesis, 475 pieces / m^2 to 620 pieces / m^2 of productive stems were kept.

The results of the studies showed that, on average, in 2011-2015, up to the XII stage of organogenesis, 409 pieces / m^2 of productive stems were kept in control. For technologies that provided increasing doses of fertilizers, the density of the productive stem varied from 479 to 554 pc / m^2. The degree of realization of productive stems was 47-65%.

Based on the results of the morphophysiological analysis, potential yields were calculated. The magnitude of the potential spring wheat crop was determined by the stage of organogenesis, the intensity of growing technology, and the weather conditions of the year. The potential spring wheat yield, estimated at the IX stage of organogenesis in the weather conditions of 2015, varied from 10.6 t / ha in control to 11.2 t / ha in resource-saving technology and up to 14.5 t / ha in increasing doses of fertilizer three times over high-intensity technology. In the drier conditions of 2013, a much lower potential crop was formed. For technologies without fertilizer application (control), its value at the IX stage of organogenesis was 7.9 t / ha. The use of resource-saving and intensive technologies allowed to increase potential yields to 10.1 t / ha, 11.5 and 11.9 t / ha, respectively, in extreme conditions of the year.

The estimated degree of realization of the potential crop in the actual one relative to the IX stage of organogenesis in 2015 was 47-61% and exceeded the average value of this indicator, which was 40-46%. In 2013, the degree of realization of the potential spring wheat crop in the actual yield relative to the IX stage of organogenesis significantly decreased and amounted to 37-42%.

Conclusions

During the years of research, the highest productivity of spring wheat agrophytocenosis of the variety Struna Mironivska - 7.87 t / ha after the soybean as precursor was obtained in 2015 by the technology, which included the introduction of P90K90N45 before sowing and N45 as fertilization on IV and N45 on VIII s.o. on the background of integrated plant protection. This yield is created by the density of the productive stem density of 550 pcs / m^2 and the productivity of the ear of 1.5 g. The level of realization of the potential yield in the actual one amounted to 54% in relation to the IX stage, while the realization of the productive stem density 54% and 38% of the kept flowers for the period from V to XII stages of organogenesis. It is established that due to the use of intensive growing technologies it is possible to partially compensate for the negative influence of weather conditions on the formation of individual elements of productivity.

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