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INFLUENCE OF ECOLOGICAL FACTOR ON *TRITICUM AESTIVUM* L. GRAINS FORMATION IN F_1 IN CROSSING VARIETIES WITH 1AL.1RS AND 1BL.1RS TRANSLOCATIONS

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The paper reveals the results of the study on soft winter wheat varieties of the V.M. Remeslo Myronivka Institute of Wheat of the National Academy of Sciences of Ukraine and the Institute of Plant Physiology and Genetics of the National Academy of Sciences of Ukraine. The findings demonstrate dependence of grain formation in the first generation of interspecific hybrids of soft winter wheat on the environmental factors and on wheat-rye translocations 1AL.1RS and 1BL.1RS in the parental forms. The results of the analysis of variance show that in the field, the efficiency of crossing and the percentage of grain formation significantly depended on the interaction of factors (47.9%, $p \leq 0.05$), weather conditions (32.2%) and the variety genotype (19. 6%) and did not depend significantly (0.3%) on unaccounted factors (coincidence of flowering dates of the components involved in hybridization). In the group of crosses 1BL.1RS / 1BL.1RS, the average percentage of grain formation was the highest for three years (2016–2018) and did not differ significantly - 50.1%; 55.5% and 49.8%. In the unfavorable 2019 it was ranked second. The maximum average indicators for the research years (48.3%) and under favorable weather conditions of 2017 (68.3%) were obtained using the crosses of the variety of Svitanok myronivskyi 1BL.1RS as a parent form, and the minimum (37.1 % and 45.2%, respectively) – using the variety of Kalynova 1BL.1RS. The results of the study show that hybrid combinations of Svitanok myronivskyi / Kalynova (56.1%), Lehenda myronivska / Kalynova (54.6%), Zolotokolosa / Svitanok myronivskyi (53.3%), Lehenda myronivska / Ekspromt (52.4%), Kolumbia / Zolotokolosa (48.1%), Svitanok myronivskyi / Lehenda myronivska (47.6%) and Svitanok myronivskyi / Zolotokolosa (46.4%) were the best in terms of the average percentage of grains formation for the research years.

Keywords: *soft winter wheat, wheat-rye translocations, grain formation, weather conditions, genotype.*

Introduction

Technological effectiveness of the variety and its ability to withstand adverse growing conditions without losing the genetic ability to form a high grain yield are the key requirements for wheat growing. A significant reserve of valuable economic traits of soft winter wheat is concentrated in the gene pool of closely related species and genera. Varieties with wheat-rye translocation are characterized by high adaptive potential, increased yield, increased protein content in the grain, and they can be more drought-resistant (Lytvynenko *et al*., 2018; Kochmarskyi *et al.*, 2010; Singh *et al*., 1990). Widespread Varieties of soft wheat with translocation 1BL / 1RS, 1AL / 1RS, as well as the replacement of chromosome 1B by 1R are widespread (Lialko *et al.*, 2018; Kozub *et al.*, 2015; Kozub *et al*., 2005; Kim *et al*., 2004).

Climate change is expected to reduce wheat grain production in key regions. Despite the fact that autumn and winter temperatures may be even lower, the overall warming effect is negative, and new varieties tend to be much less resistant to stress temperatures, lack of moisture, *etc*., than previously created ones. The main way to overcome the negative impact of climate change on yields is to work out statistical models that can minimize risks and allow to develop a system of measures aimed to prevent crop losses. In this aspect, the creation and introduction of varieties with high adaptive potential is considered a major factor in overcoming possible risks (Bakumenko *et al.*, 2019).

Both closely related wheat species and more distant ones are used as donors of valuable economic traits: *Aegilops, Agropyron, Hordeum, Secale, etc.* To date, about 70 wheat-alien translocations have been registered in the soft wheat genome, which affect its resistance to diseases and pests, as well as other valuable breeding traits (Crespo-Herrera *et al.*, 2017; Gorash *et al.*, 2014). However, only five of them are of economic significance. These include wheat-rye translocations of 1BL.1RS and 1AL.1RS, formed by the transfer of the short arm of 1R rye chromosome to the long arm of 1B or 1A wheat chromosome, respectively (Howell *et al* ., 2014; Kim *et al.*, 2004; Rabinovich, 1998). Varieties with wheat-rye translocation are characterized by high adaptive potential, increased yield, increased protein content in the grain, and they can be more drought-resistant (Bakumenko *et al.*, 2019).

Studies by leading scientists (Bakumenko *et al.*, 2019; Shestopal *et al.*, 2014; Vlasenko *et al*., 2014; Kozub *et al*., 2014, 2010; Hoffmann, 2008) have proven the benefits of ways to increase the genetic diversity of source material in winter wheat breeding using the carriers of wheat-rye translocations, which can be considered as a model of successful use of alien material to improve the culture. These translocations are of maximum interest to breeders due to the positive genetic influence on valuable economic and biological traits and properties including productivity, resistance to abiotic and biotic factors. The potential of wheat-rye translocations for the varieties creation has not depleted since the translocations manifestation is largely determined by the genotypic environment of soft winter wheat varieties. Therefore, the studies aimed to reveal the translocations possibilities of successful use in breeding are relevant.

The aim of the study was to determine the dependence of seed formation in the first generation of soft winter wheat intervarietal hybrids on environmental factors and the presence of wheat-rye translocations 1AL.1RS and 1BL.1RS in the parent forms.

Materials and Methods

The material for the research was varieties of soft winter wheat bred by the V.M. Remeslo Myronivka Institute of Wheat of NAAS of Ukraine (MIW) and the Institute of Plant Physiology and Genetics of NAAS of Ukraine (IPPG). The field experiments were carried out in 2014/15 - 2018/19 on the experimental fields of MIW. Parent forms were sown by hand on 0.3m^2 plots. Phenological observations, assessments and accounting were performed according to generally accepted methods (Dospehov, 1985). Ears with hybrid seeds of the first generation were threshed by hand. Weather conditions over the research years were contrasting, especially those during the hybridization (May), which affected the percentage of hybrid grain formed and allowed to obtain objective results.

Results

Vegetation weather conditions in 2015/16 – 2018/19 during the study period were generally favorable for the growth and development of winter wheat plants, but the average annual air temperature and precipitation differed from the average long-term data (Table 1).

Table 1. Precipitation and air temperature during the growing season of winter wheat (2014/15 –2018/19)

Year	Months												$\bar{X}$	%
	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII		
Precipitation, mm														
2015/16	10	44	27	46	18	72	52	36	55	92	69	19	541	88
2016/17	37	2	74	44	31	31	33	13	43	24	20	102	454	74
2017/18	19	13	75	52	115	72	37	94	22	33	96	79	707	115
2018/19	14	79	28	20	72	40	26	27	23	50	87	50	516	84
PA*	62	58	39	42	41	34	30	35	42	55	91	84	613	
Air temperature, °C													$\bar{X}$	+
2015/16	21.6	18.2	7.1	4.6	1.8	-5.9	2.4	4.1	12.4	15.2	20.1	22.2	10.3	1.3
2016/17	20.9	15.7	6.6	1.3	-1.8	-5.3	-2.7	6.1	10.4	15.4	20.6	21.0	9.0	0.7
2017/18	22.4	17.0	8.5	3.4	2.1	-3.0	-3.7	-1.8	13.2	18.4	20.2	20.9	9.8	0.6
2018/19	14.6	11.4	5.7	-2.7	-3.7	-7.9	-2.0	1.0	4.6	12.3	16.2	13.6	5.3	3.0
PA*	19.7	14.4	8.4	1.9	-2.3	-4.0	-3.4	1.5	9.2	15.5	18.5	20.5	8.3	

* PA – perennial averages (1980–2014)

During the growing season of 2015/16, the average annual air temperature was 10.3 °C, which is 2.3 °C higher than the long-term value (8.3 °C). Its absolute maximum (26.9 °C) was observed in the third decade of

June, the minimum (-18.3 °C) was observed in the first decade of January. The amount of precipitation reached 541 mm, which is 72 mm less than the average long-term norm (613 mm). The amount of precipitation, by seasons, was: autumn 2015 - 117 mm; winter 2015–2016 - 142 mm; spring and summer 2016 - 164 and 88 mm, respectively. The highest precipitation level was in May (92 mm), June (69) and January (72), the lowest - in December (18). Indices of ten-day period average air temperature and precipitation in May are especially important for the selection process since this is the time the hybridization is carried out (Fig. 1).

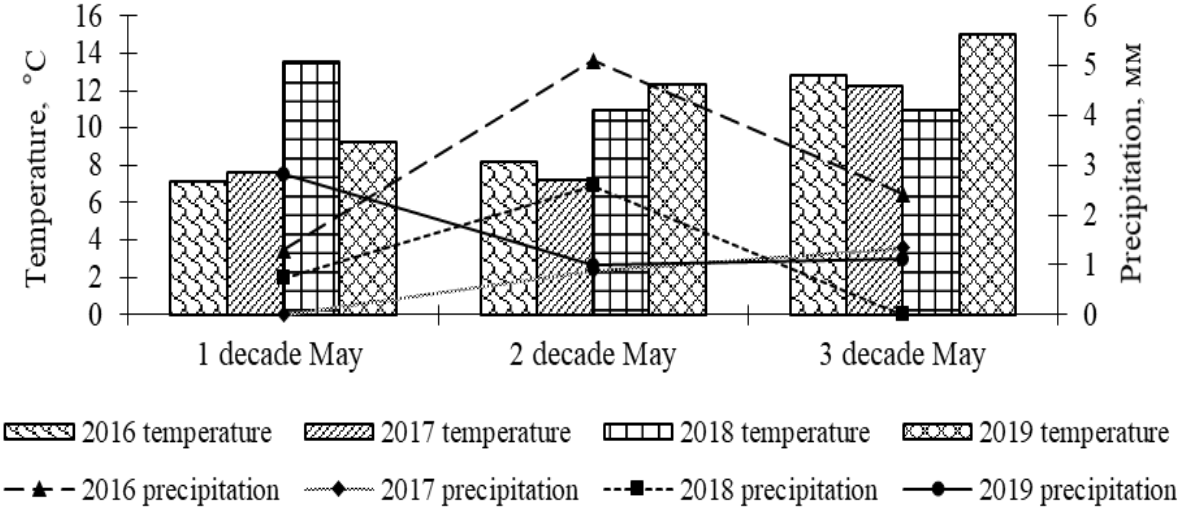

Fig. 1. Hydrothermal conditions in the period of "earing-flowering" of winter wheat

In the third decade of May 2016, during castration and pollination, there was a significant amount of rainfall and low air temperature, which negatively affected the percentage of seed formed.

In 2016/17, there were unfavorable weather conditions for winter wheat plants growth and development. During the growing season, the amount of precipitation was 454.3 mm (74.1% to the long-term amount). Droughts in the period from stem elongation to threshing (79.6 mm, average long-term index - 204.3 mm) against the background of increased air temperature during the period of grain filling (+22.2 °C) and insufficient storage of productive moisture in the soil resulted in a decrease in 1000 grains weight. In the first decade of May 2017, the average air temperature was 7.6 °C, and the amount of precipitation was 0.0 mm; in the second decade it was - 7.2 °C and 0.9 mm, respectively, in the third - 12.2 °C and 1.3 mm, respectively (Fig. 1). Weather conditions were favorable for pollination, which had a positive effect on the percentage of hybrid grain formation.

Significant temperature variations (long cool periods succeeded very warm and hot ones) was a characteristic feature of the spring and summer growing seasons in 2018 but it was favorable for the grain yields formation since the air temperature mostly did not reach the level of thermal stress in winter crops growing seasons. Meteorological summer (average daily air temperature exceeds +15 °C) began at the end of April. In the first decade of May 2018, the average air temperature was 13.6 °C, the amount of precipitation was 0.7 mm; in the second decade - 11.0 °C and 2.6 mm, respectively; in the third - 10.9 °C and 0.0 mm, respectively (Fig. 1). The low temperature of the air during pollination negatively affected the proportion of the seed formed during hybridization.

During the vegetation period of 2018/19, the average annual air temperature was 5.3 °C, which is 3.0 °C higher than the long-term index (8.3 °C). The amount of precipitation reached 516 mm, which is 84 mm less than the average long-term norm (613 mm). Drought, initially air one followed by air-soil drought was caused by a severe deficit of precipitation during the period of April - the first half of June and by high (3-4.5 °C above normal) temperature during this period. May was abnormally warm and dry. In the first decade of May 2019, the air temperature was 9.3 °C, the amount of precipitation was 2.8 mm; in the second decade - 12.4 °C and 1.0 mm, respectively; in the third - 15.0 °C and 1.1 mm, respectively (Fig. 1). Weather conditions were most unfavorable (strong wind gusts, short-term rains) for pollination, which negatively affected the percentage of hybrid grain formation.

Thus, the temperature regime and the weather deviations over the research years (sharp cooling or high day temperatures, heavy rains with wind, reduced solar insolation) in the third decade of May were the key factors that affected the hybridization rate.

In 2016–2019, intraspecific hybridization was carried out on the field at the end of the second and the beginning of the third decade of May. As a result, 88,528 flowers were castrated and pollinated in 60 crossing combinations and 17,648 F1 grains were obtained. The studied varieties are of medium ripeness, so the periods of earing and flowering mostly coincided, which had a positive effect on the seed formation percentage.

According to the results of analysis of variance (Fig. 2) it was found that the efficiency of crossing and, accordingly, the percentage of seed formation on the field significantly depended on the interaction of factors (47.9%, $p \leq 0.05$), weather conditions of the year (32.2 %), the variety genotype (19.6%) and insignificantly (0.3%) – on neglected factors (coincidence of flowering periods of the components involved in hybridization).

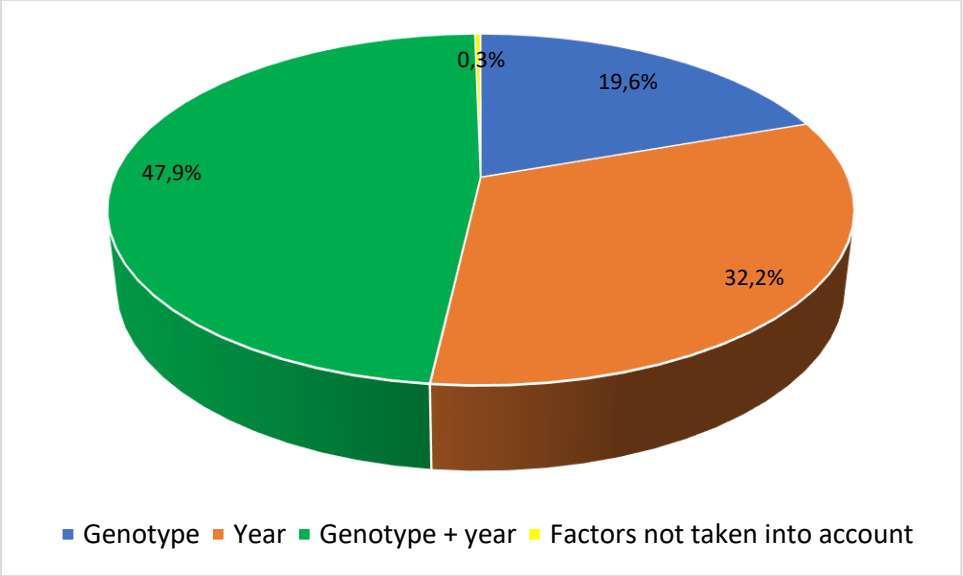

Fig. 2. Influence of the factor on the indicators of soft winter wheat grain formation under crossing varieties-carriers wheat-rye translocations (average for 2014–2019)

Hydrothermal regimes in May during the study years significantly affected the percentage of hybrid grain formation and the extent of variation. The influence of the conditions of the year significantly outweighed the influence of the variety - the average percentage of hybrid grains formation in the favorable 2017 was the maximum for all groups of crosses (Table 2).

Table 2. Statistical indicators of grains formation in soft winter wheat hybrid in the hybridization of initial forms-carriers of wheat-rye translocations

Statistical indicators	Year			
	2016	2017	2018	2019
1AL.1RS / 1AL.1RS				
$\bar{X}$	36.6	56.5	37.3	30.1
X_{min}	24.5	39.7	25.8	21.1
X_{max}	69.5	69.1	55.1	37.4
R	45.0	29.4	29.3	16.3
σ	18.1	12.5	13.2	7.2
V, %	49.4	22.1	35.4	23.9
1BL.1RS / 1BL.1RS				
$\bar{X}$	50.1	55.3	49.8	31.4
X_{min}	26.7	21.4	21.8	21.3
X_{max}	80.1	75.2	72.7	39.4
R	54.0	55.1	51.0	17.9
σ	20.3	20.2	19.3	7.6
V, %	40.5	36.5	38.8	24.2
1AL.1RS / 1BL.1RS				
$\bar{X}$	43.2	63.9	41.4	28.4

X_{min}	27.7	51.5	22.6	20.5
X_{max}	67.3	77.4	77.3	44.3
R	39.5	25.9	54.7	23.8
σ	15.3	8.3	17.1	8.5
V, %	35.4	13.0	41.3	29.9
1BL.1RS / 1AL.1RS				
$\bar{X}$	40.4	55.0	35.4	34.3
X_{min}	22.3	22.6	22.4	22.4
X_{max}	60.7	80.3	55.6	46.4
R	38.4	57.7	33.2	24.0
σ	13.1	18.8	13.8	8.3
V, %	32.4	34.2	39.0	24.2

The opposite trend was observed in the worst weather conditions in May 2019 - indicators $\bar{X}$, Xmin, Xmax were noted at the minimum level, which confirms the significant impact of the year weather conditions on the average percentage of grain formation during the hybridization.

The minimum average coefficient of variation (V,%) was observed under contrasting weather conditions of May 2019, 2017 - 25.6 and 26.8%, respectively. Under favorable conditions of 2017 in each group of $\bar{X}$ crossing and its maximum (Xmax) values were the highest for the research years. The share of success in the hybridization was significantly dependent on genotype. The highest level of cross-compatibility was observed in the 1BL.1RS / 1BL.1RS crossing group - the average percentage of hybrid grain formation was the highest (Fig. 3).

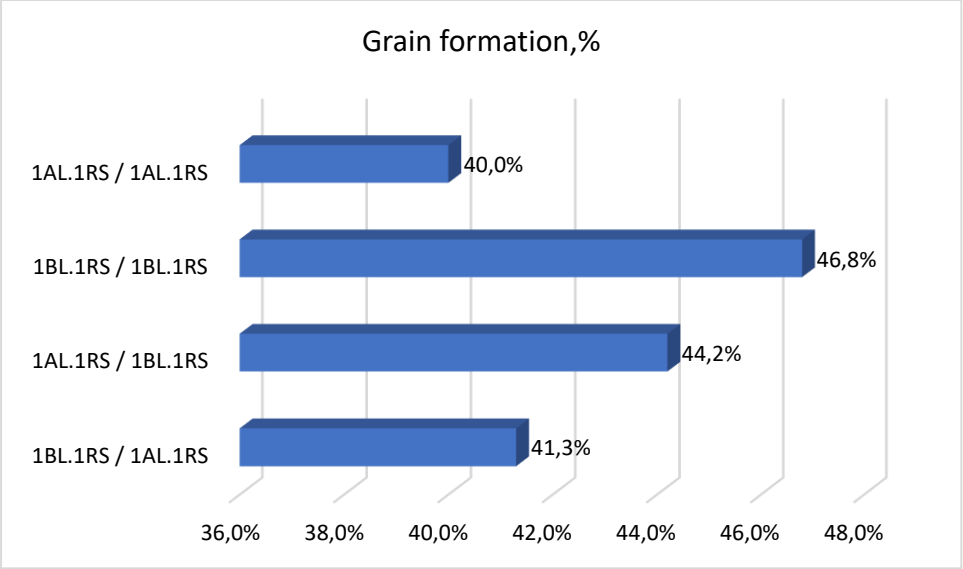

Fig.3. The share of winter wheat grains formation in F1 under crossing varieties - carriers of wheat-rye translocations (average for 2015–2019)

In the group of crosses 1BL.1RS / 1BL.1RS, the average indicator of grain formation ($\bar{X}$) was the highest during three (2016–2018) years and remained nearly the same - 50.1; 55.5 and 49.8%, respectively. In the unfavorable 2019 it was listed second (Table 3).

Table 3. Soft winter wheat grains formation involving hybridization of initial forms-carriers of wheat-rye translocations

Hybrid crossbreeding combination		Grain formation,%			
		Year			
		2016	2017	2018	2019
1AL.1RS / 1AL.1RS[2]					
1	Zolotokolosa / Kolumbiia	25.4	38.4	25.0	34,2
2	Kolumbiia / Zolotokolosa	69.5	56.6	28.1	38,2
3	Zolotokolosa / Ekspromt	26.6	64.3	52.9	37,1
4	Ekspromt / Zolotokolosa	47.4	66.7	29.7	21,6
5	Kolumbiia / Ekspromt	26.7	69.5	55.2	24,3
6	Ekspromt / Kolumbiia	24.5	43.4	32.5	25,4
$\bar{X}$		36,7	56.5	37.2	30.1
1BL.1RS / 1BL.1RS					
7	Svitanok myronivskyi / Lehenda myronivska	37.6	67.2	62.3	23,2
8	Lehenda myronivska / Svitanok myronivskyi	65.2	68.6	36.3	39,4
9	Svitanok myronivskyi / Kalynova	53.9	76.4	72.6	21,5
10	Kalynova / Svitanok myronivskyi	37.1	56.2	43.4	33,1
11	Kalynova / Lehenda myronivska	26.3	21.3	21.5	39,3
12	Lehenda myronivska / Kalynova	80.3	43.2	62.5	32,2
$\bar{X}$		50,1	55.5	49.8	31.5
1AL.1RS / 1BL.1RS					
13	Ekspromt / Svitanok myronivskyi	32.3	67.7	44.8	29,2
14	Ekspromt / Lehenda myronivska	27.7	51.4	34.3	44,3
15	Ekspromt / Kalynova	67.3	56.9	35.1	22,3
16	Zolotokolosa / Lehenda myronivska	28.1	61.6	31.2	20,5
17	Zolotokolosa / Kalynova	44.6	63.9	77.3	21,4
18	Zolotokolosa / Svitanok myronivskyi	54.2	77.4	59.5	22,2
19	Kolumbiia / Svitanok myronivskyi	31.4	74.3	39.2	38,3
20	Kolumbiia / Lehenda myronivska	38.2	63.9	22.6	33,4
21	Kolumbiia / Kalynova	63.9	58.7	28.5	22,8
$\bar{X}$		43,1	64.0	41.4	28.3
1BL.1RS / 1AL.1RS					
22	Kalynova / Ekspromt	55.3	53.1	32.8	32,3
23	Kalynova / Kolumbiia	28.9	72.6	22.4	29,4
24	Kalynova / Zolotokolosa	36.3	22.6	55.6	22,4
25	Svitanok myronivskyi / Kolumbiia	47.8	44.7	54.9	33,4
26	Svitanok myronivskyi / Zolotokolosa	30.7	80.3	28.3	46,4
27	Svitanok myronivskyi / Ekspromt	48.6	73.1	27.9	34,2
28	Lehenda myronivska / Zolotokolosa	22.3	48.1	22.9	25,3
29	Lehenda myronivska / Ekspromt	60.7	61.3	49.2	38,4
30	Lehenda myronivska / Kolumbiia	33.6	38.2	25.2	46,1
$\bar{X}$		40,5	54.9	35.5	34.2

In 2017, under the optimal weather conditions during pollination, maximum values $\bar{X}$ (63.9%), Xmax (51.5%) and the minimum coefficient of variation (13.0%) were obtained in the group of 1AL.1RS / 1BL.1RS crosses, which indicates a significant positive impact of the environment on the success rate in this group.

Almost half (46.7%) of the hybrid combinations received an average percentage of grain formation ranging 41-50, and for one fifth it made more than 50 units (Fig. 4).

The level of hybrid grains formation depends not only on the environmental conditions during pollination. It is also contributed by genotypic diversity of the original components of crossbreeding. The maximum averages for four years of the research (48.3%) under favorable weather conditions in 2017 (68.3%) were obtained in crosses involving the variety of Svitanok myronivskyi 1BL.1RS as a maternal form, and the

minimum (37.1% and 45.2%, respectively) with the variety of Kalynova 1BL.1RS. It was also found out that the latter variety was a better pollinator: the average percentage of grain formation in hybrid combinations with the variety of Kalynova 1BL.1RS was the maximum and made 50.3. The minimum (36.3%) indicator was observed for the variety of Kolumbiia 1AL.1RS.

The following hybrid combinations were determined the best in terms of the average percentage of grain formation over the research years: Svitanok myronivskyi / Kalynova (56.1%), Lehenda myronivska / Kalynova (54.6%), Zolotokolosa / Svitanok myronivskyi (53.3%), Lehenda myronivska / Ekspromt (52.4%), Kolumbia / Zolotokolosa (48.1%), Svitanok myronivskyi / Lehenda myronivska (47.6%) and Svitanok myronivskyi / Zolotokolosa (46.4%). These had the highest rate under both favorable weather conditions of 2017 and the worst weather conditions of May 2019.

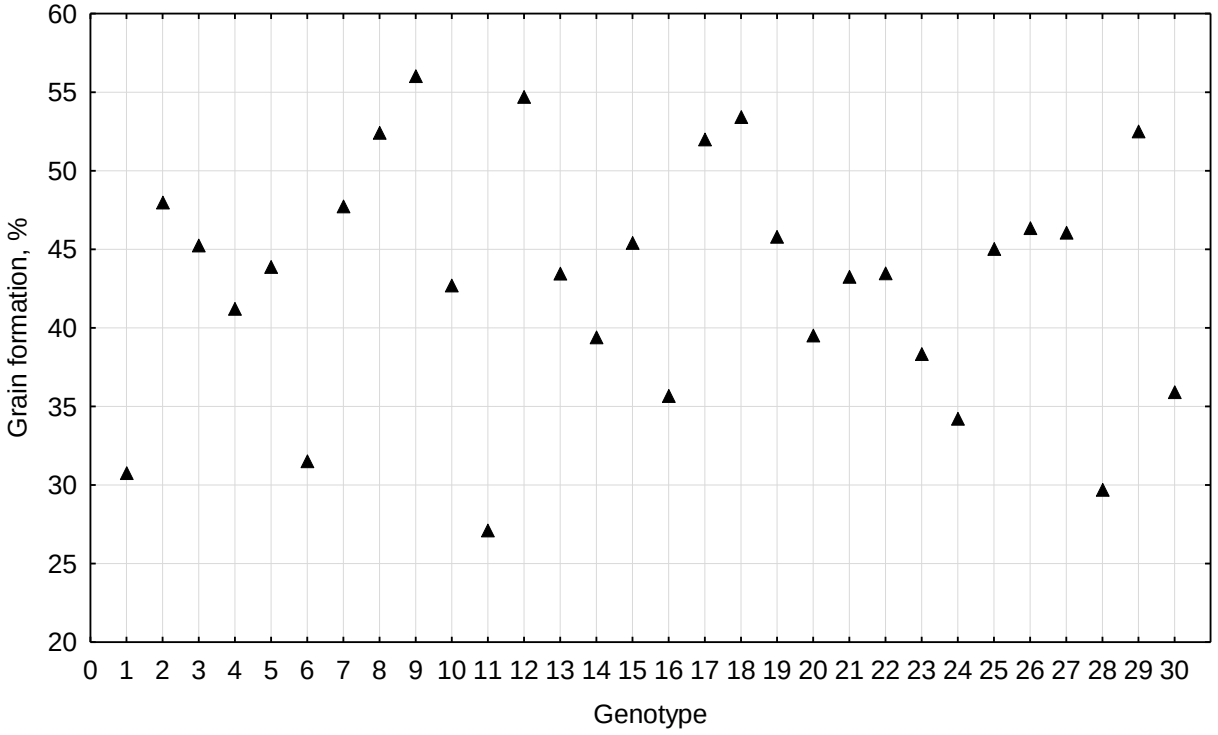

Fig. 4. The average frequency of grain formation in F_1 hybrid combinations of soft winter wheat under crossing varieties-carriers of wheat-rye translocations, average for 2016-2019.

Conclusions

1. It has been found out that the efficiency of crossing in the field the and, accordingly, the percentage of grain formation significantly depended on the interaction of factors (47.9%, $p \leq 0.05$), weather conditions of the year (32.2%) and the variety genotype (19.6%). The impact of unaccounted factors (coincidence of flowering dates of components involved in hybridization) was insignificant (0.3%).

2. The research has shown that the average percentage of grain formation in the group of crosses 1BL.1RS / 1BL.1RS was the highest during three years (2016–2018) and remained nearly the same - 50.1; 55.5 and 49.8%, respectively. In the unfavorable 2019 it was listed second.

3. The maximum average indicators for the research years (48.3%) and under favorable weather conditions of 2017 (68.3%) were obtained using the crosses of the variety of Svitanok myronivskyi 1BL.1RS as a parent form, and the minimum (37.1 % and 45.2%, respectively) – using the variety of Kalynova 1BL.1RS.

4. It was found that the Kalynova variety was the best pollinator: the average percentage of grain formation in hybrid combinations this variety was the highest and made 50.3%. The minimum (36.3%) indicator was observed for the variety of Kolumbiia 1AL.1RS.

5. The results of the study show that hybrid combinations of Svitanok myronivskyi / Kalynova (56.1%), Lehenda myronivska / Kalynova (54.6%), Zolotokolosa / Svitanok myronivskyi (53.3%)), Lehenda myronivska / Ekspromt (52.4%), Kolumbia / Zolotokolosa (48.1%), Svitanok myronivskyi / Lehenda myronivska (47.6%) and Svitanok myronivskyi / Zolotokolosa (46.4%) were the best in terms of the average percentage of grain formation for the research years.

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ВПЛИВ ЕКОЛОГІЧНОГО ЧИННИКА НА ЗАВ'ЯЗУВАННЯ ЗЕРЕН *TRITICUM AESTIVUM* L. У F_1 ПРИ СХРЕЩУВАННІ СОРТІВ ІЗ 1AL.1RS ТА 1BL.1RS ТРАНСЛОКАЦІЯМИ

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Проведено дослідження сортів пшениці м'якої озимої селекції Миронівського інституту пшениці імені В. М. Ремесла НААН України та Інституту фізіології рослин і генетики НАН України. Виявлено залежність зав'язування насіння в першому поколінні міжсортових гібридів пшениці м'якої озимої від факторів впливу екологічних чинників та наявності пшенично-житніх транслокацій 1AL.1RS та 1BL.1RS у батьківських форм. За результатами дисперсійного аналізу встановлено, що в польових умовах ефективність схрещування та відсоток зав'язування істотно залежали від взаємодії факторів (47,9 %, $p \leq 0,05$), погодних умов року (32,2 %) і генотипу сорту (19,6 %) та не істотно (0,3 %) – від неврахованих факторів (збіг строків цвітіння компонентів, залучених до гібридизації). У групі схрещувань 1BL.1RS / 1BL.1RS середній показник відсотку зав'язування був найбільшим впродовж трьох років (2016–2018) та істотно не відрізнявся – 50,1 %; 55,5 % і 49,8 %. У несприятливому 2019 р. займав другу позицію. Максимальні середні показники за роки досліджень (48,3 %) і в сприятливих погодних умовах 2017 р. (68,3 %) одержали в схрещуваннях за використання в якості материнської форми сорту Svitanok myronivskyi 1BL.1RS, а мінімальні (37,1 % і 45,2 %) – сорту Kalynova 1BL.1RS. Кращими за середнім відсотком зав'язування були гібридні комбінації: Svitanok myronivskyi / Kalynova (56,1 %), Lehenda myronivska / Kalynova (54,6 %), Zolotokolosa / Svitanok myronivskyi (53,3 %), Lehenda myronivska / Ekspromt (52,4 %), Kolumbiia / Zolotokolosa (48,1 %), Svitanok myronivskyi / Lehenda myronivska (47,6 %) і Svitanok myronivskyi / Zolotokolosa (46,4 %)

Ключові слова: пшениця м'якої озима, пшенично-житні транслокації, зав'язуваність, погодні умови, генотип.