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Influence of climatic factors on *Triticum aestivum* L. grains formation in F1 crossing varieties with 1AL.1RS and 1BL.1RS translocations

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The paper reveals the study results 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 the 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 (the coincidence of flowering dates of the components involved in hybridization). In the 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 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

The 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 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, and 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. Even though autumn and winter temperatures maybe lower, the overall warming effect is negative, and new varieties tend to be much less resistant to stress temperatures, lack of moisture, than previously created ones. The primary way to overcome the negative impact of climate change on yields is to work out statistical models that can minimize risks and develop system of measures to prevent crop losses. In this aspect, creating and introducing varieties with high adaptive potential is considered a significant 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,*. To date, about 70 wheat-alien translocations have been registered in the soft wheat genome, which affects its resistance to diseases and pests and 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 transferring 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 variety creation has not depleted since the translocations manifestation is primarily 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 study aimed 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 research material was varieties of soft winter wheat selected 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 winter wheat season (2014/15 –2018/19).

Year	Months												$\overline{X}$	%
	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												$\overline{X}$	+
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, 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 essential for the selection process since this is when the hybridization is carried out (Fig. 1).

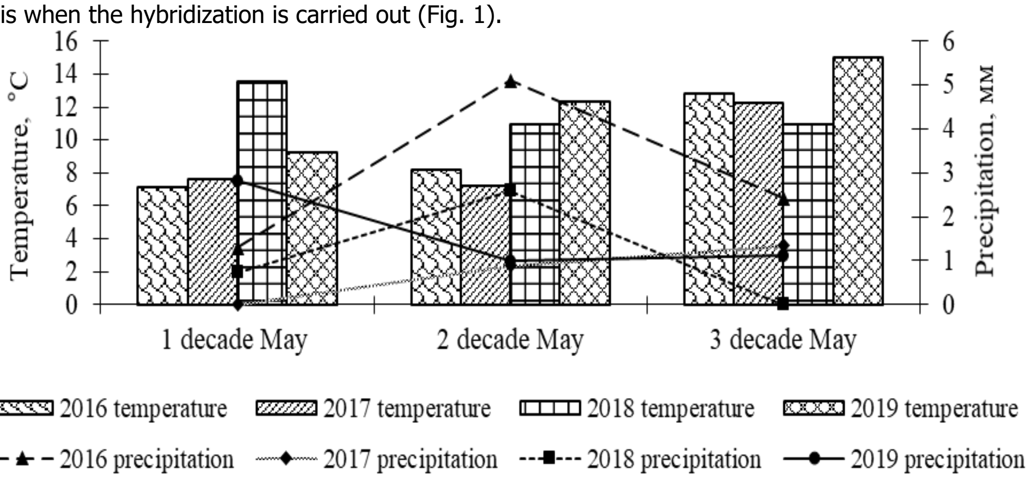

Fig. 1. Hydrothermal conditions in the period of "earing-flowering" of winter wheat

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 positively affected 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 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 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 the 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 positively affected the seed formation percentage.

According to the results of the 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 (the coincidence of flowering periods of the components involved in hybridization).

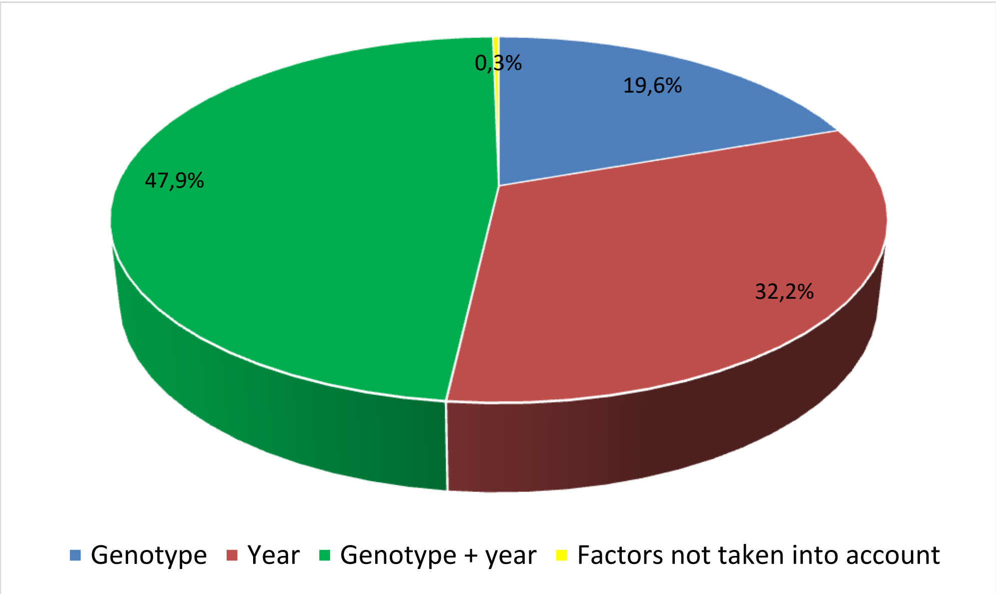

Fig. 2. Influence of the factor on the indicators of soft winter wheat grain formation under crossing varieties-carriers wheat-rye translocations (average for 2014–2019)

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 year's conditions significantly outweighed the variety - the average percentage of hybrid grains formation in favorable conditions of 2017 was the maximum for all crosses groups (Table 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).

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

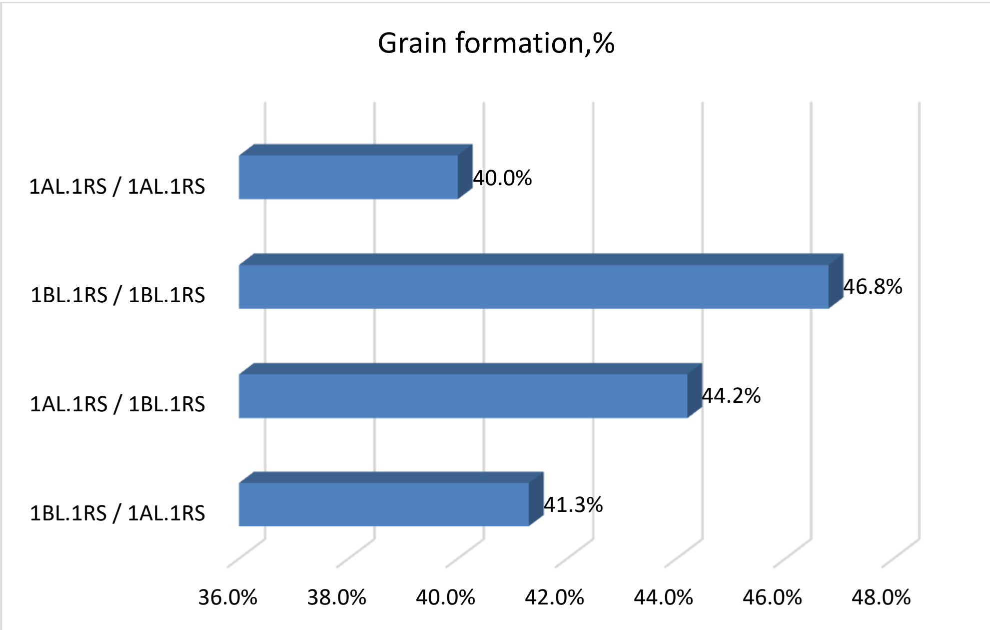

Fig. 3. The share of winter wheat grains formation in F1 under crossing varieties - carriers of wheat-rye translocations (average for 2015–2019).

In the 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 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
$\overline{X}$		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
$\overline{X}$		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
$\overline{X}$		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	384
30	Lehenda myronivska / Kolumbiia	33.6	38.2	25.2	46.1
$\overline{X}$		40,5	54.9	35.5	34.2

In 2017, under the optimal weather conditions during pollination, maximum values $\overline{X}$ (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 the 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.

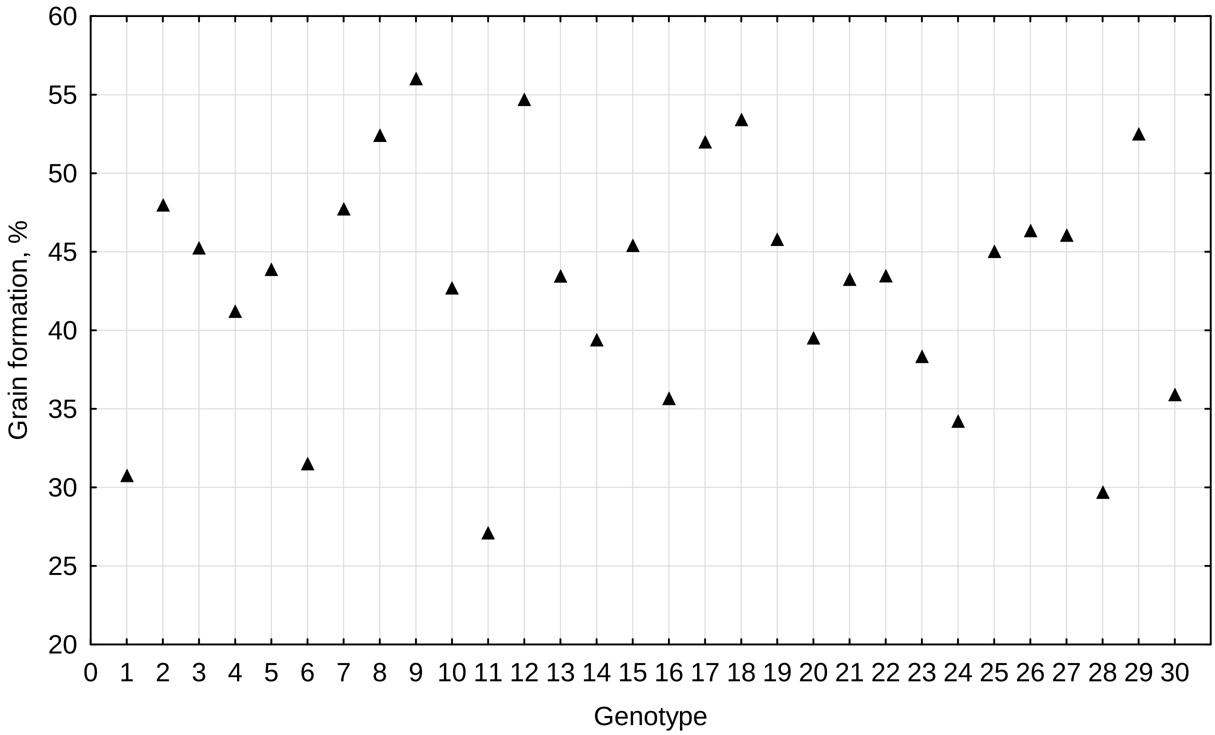

Fig. 4. The average frequency of grain formation in F_1 hybrid combinations of soft winter wheat under crossing varieties-carriers of wheat-rye translocations, the average for 2016-2019.

Conclusion

1. It has been found out that the efficiency of crossing in the field 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 (the 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. We found that the Kalynova variety was the best pollinator: the average percentage of grain formation in hybrid combinations 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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