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Genetics and Selection

Crossability of Endemic Species and Aboriginal Varieties of Georgian Wheat and Traits in F1

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ABSTRACT. The research shows that Georgia is a primary centre of the origin and diversity of cultivated wheat, distinguished from other countries by a high level of endemism. It is proved that Georgian endemic species of wheat have played an important role in the evolution of the genus Triticum and process of wheat selection on a global scale. New species, genera, cultivars and varieties of wheat have been obtained on the basis of wheat species endemic to Georgia. Their genotype bears genes which allow to obtain wheat species of a new type with high immunity and quality features. Issues of crossability of endemic species of Georgian wheat with other species as well as with aboriginal and selection varieties of soft wheat, germination capacity of obtained hybrid grains and viability of plants of the first generation are discussed in the present paper. Peculiarities of inheritance of economically important morphological traits in the first generation of plants are shown. *© 2012 Bull. Georg. Natl. Acad. Sci.*

***Key words**: crossability, genotype, lethal genes.*

It has been established by Georgian and foreign scientists that countries of Western Asia (Georgia, Azerbaijan, Turkey, Iran, Syria, Israel), where a total of 892 species and varieties of wheat have been identified and registered, dominate in the number of species and varieties of wheat among Western Asian and Central Asian (Turkmenistan, Afghanistan, India, Pakistan) centres. Number of species and varieties of wheat registered in countries of Western Asia is 2.5 times and even higher than in countries of Central Asia [1-3].

Among countries of Western Asia those of the South Caucasus are distinguished for the highest number of wheat species and varieties. Turkey holds the second position in this respect [1-3]. Georgia holds the first position by the number of wheat species and especially by the number of cultivated endemic species of wheat, being at the same time distinguished for a high level of endemism [1-12].

The following cultivated natural endemic species have been found in Georgia (Western part of the country): Chelta Zanduri (*T. timopheevii* – 2n=28), Georgian Asli (*T. georgicum* – 2n=28), Makha (*T.macha* – 2n=42). The latter is a combined species, comprising two species: Gvatsa Makha (*T. tubolicum*) and Chelta Makha (*T. imereticum*), hexaploid Zanduri

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(*T. zhukoskyi* – 2n=42) and Dika (*T. carthlicum* – 2n=28). Varieties of the latter species have been reported from Armenia and Turkey as well [1-12].

Study of Georgian endemic species of wheat, investigation of the processes of their evolution has allowed to conclude that a wide process of origination of wheat species took place on the territory of Georgia, which had a great impact on the process of evolution of the wheat genus. To the present day new species of wheat are created with the participation of *T.carthlicum* and *T. timopheevii* [1-3,12]. The above discussed facts show that investigation of genetic and selection values of Georgian endemic wheat species is significant not only from theoretical-scientific viewpoint, but is very important from the practical viewpoint too.

Material and Methods

The following wheat species - Georgian endemics (*T. dicoccoides, T.durum, T. turgidum, T. polonicum*); varieties (var. *timopheevii*, var. *viticalosum*, var. *chvamlicum*, var. *stramineum*, var. *rubiginosum*, var. *fuliginosum*, var. *zhukovskyi*, var. *subletschumicum*, var. *macha*, var. *palaeoimereticum*, var. *palaeo-colhicum*) and 32 aboriginal and selection varieties of Georgian wheat, held at the gene depository of the Department of Genetics, Selection and Seed Farming of the Georgian Agrarian Institute (later re-organized to the Georgian Agrarian University) have been used as initial material for the trials.

Methods of intraspecific hybridization, back-crossing and genetic analysis have been applied in our studies. Pollination of castrated spikes was carried out using methods of free (natural), compulsory (artificial) and compulsory (artificial)-free (natural) pollination. In order to obtain each combination 100 flowers were castrated and pollinated.

The obtained hybrid grains were sown outdoors, in the field. Their growth, inventory and monitoring were carried out according to the generally accepted methods.

Results and Discussion

Analysis of experimental material obtained as a result of crossing endemic and other species of Georgian wheat with aboriginal and selection varieties of soft wheat has shown that the process of crossing proceeds without any kind of difficulties.

It became clear that Georgian aboriginal varieties of soft wheat reveal non-uniformity while crossing with tetraploid and hexaploid species, i.e. they are heterogenous. The percentage of the setting of hybrid grains was found to be dependent on the female parent species participating in the process of crossing. When crossing tetraploid and hexaploid species, the setting of hybrid grains is high if tetraploid species is pollinated with the pollen grains of a hexaploid species. The rate of hybrid grains setting greatly depends on ecological-genetic peculiarities i.e. the genotype of the soft wheat variety. Crossing of East Georgian varieties of soft wheat with tetraploid and hexaploid species proceeds with difficulty, while crossing of West Georgian varieties is easier. The highest number of hybrid grains is obtained when the hybrid varieties of soft wheat participate in the process of crossing. At reciprocal crossing of species with different chromosome numbers the difference is noted in the extent of filling of hybrid grains of the first generation. Filling of hybrid grains is higher when the species with higher chromosome number participates in crossing as a female form (Table 1).

Study of the germination capacity of grains of the first hybrid generation has revealed a certain regularity between the rate of grain setting and germinability while crossing varieties of Georgian soft wheat with tetraploid wheat species (Table 2). When hybrid grains setting is high, germination percent of grains decreases and vice versa. Germination capacity of hybrid grains is significantly higher when soft wheat participates in crossing as a female form. Germination capacity of such hybrid grains is to a great extent dependent on the genotype of a soft wheat. Germination capacity of hybrid grains is higher when heterozygous soft wheat participates in the

Table 1. Setting of hybrid grains

NN	Hybrid combination	Number of pollinated flowers	Number of grain setting	Percentage of grain setting, %	±*m*	*t*
1	Georgian varieties of soft wheat x *T. durum* var. *coerulescens* canescens	5600	1461	26.1 (21.8-29.5) P=3.8	0.94	
	Reversed combination	5600	2978	53.1 (45.6-60.2) P=2.0	1.03	18.1
2	Georgian varieties of soft wheat x *T. turgidum* var. *striatum*	8000	2061	24.8 (20.0-31.4) P=4.1		
	Reversed combination	8000	3491	43.6 (41.7-54.5) P=2.7	1.3	11.8
3	Georgian varieties of soft wheat x *T. polonicum* var. *villosum*	8000	315	39.4 (32.0-50.0) P=3.4	1.01	
	Reversed combination	8000	479	59.8 (40.0-70.0) P=2.3	0.96	10.4
4	Georgian varieties of soft wheat x *T. carthlicum* var. *stramineum*	7000	1443	20.6 (11.2-27.8) P=3.4	0.71	
	Reversed combination	7000	2956	42.2 (28.6-52.2) P=2.5	1.03	14.05
5	Georgian varieties of soft wheat x *T. dicoccoides* var. *arabicum*	6300	1156	18.3 (11.8-24.6) P=2.9	0.56	
	Reversed combination	6300	819	28.8 (21.8-37.0) P=2.9	0.92	8.04
6	Georgian varieties of soft wheat x *T. Zhukovskyi*	5600	475	8.61 (3.3-14.7) PP=2.4	0.98	
	Reversed combination	5600	621	11.5 (5.4-17.9) P=2.1	1.02	3.4
7	Georgian varieties of soft wheat x *T. timopheevii*	1600	67	4.1 (3.3-5.0) P=2.0	0.7	
	Reciprocal combination	1600	35	2.5 (1.5-2.75) PP=2.3	0.5	2.3
8	*T. carthlicum* x *T. turgidum*	1400	462	33.0 (30.1-40.2) P=3.5	1.23	
	Reversed combination	1400	578	41.2 (39.5-47.0) P=2.7	1.08	4.5
9	*T.carthlicum* x *T.dicoccoides*	1100	316	28.7 (27.7-29.5) P=3.1	0.93	
	Reversed combination	1100	401	36.5 (35.5-38.0) P=2.3	0.81	5.6
10	*T.carthlicum* x *T.dicoccoides*	1800	610	33.0 (30.5-36.5) P=2.8	0.96	
	Reversed combination	1800	767	42.6 (41.5-45.5) P=1.8	1.18	4.8
11	*T. turgidum* x *T. durum*	700	1400	20.0 (18-23) P=4.3	0.87	
	Reversed combination	700	169	24.1 (22-28) P=4.3	1.0	2.2
12	*T. durum* x *T. dicoccoides*	1500	383	25.5 (25-26) P=4.2	1.1	
	Reversed combination	1500	459	30.6 (29.3-31.7) P=4.1	1.1	3.2

process of crossing. Hybrid grains, obtained as a result of crossing Georgian soft wheat with *T.timopheevii* or *T. Zhukovskyi* are characterized by a comparatively high viability if the female form in crossing process is *T. timopheevii* or *T. Zhukovskyi*. Grains of intraspecific hybrids are characterized by high germination capacity when the cultivated tetraploid or hexaploid species are both parental

forms. Germination capacity of hybrid grains obtained as a result of crossing cultivated species of wheat with *T. carthlicum* is high when *T. carthlicum* is the maternal form while crossing (Table 2).

The following general regularity has been revealed in the survival capacity of intraspecific hybrid plants of the first generation (Table 2): there is a certain relationship between the setting of hybrid grains in species crossing and the capacity for survivability of plants of the first generation. When the percentage of hybrid grain setting is high, germination capacity and survival rate of plants of the first generation decrease and vice versa. The number of survived plants of the first generation is greatly affected by the level of expression of lethal genes.

Study of morphological traits in the hybrids of the first generation allowed to establish that dominant character of such traits as the absence of an awn, red or black coloration, red color of grain, downiness of leaves, fragility of spike.

Study of the duration of the vegetation period in hybrids of the first generation allowed to establish that inheritance of this index is of intermediate character.

Resistance to diseases in hybrids of the first generation is of dominant character when the hybrid

Table 2. Some indices of viability of hybrids of the first generation

NN	Hybrid combination	Germination %	Survival capacity %
1	Georgian varieties of soft wheat x *T. durum* var. coerulescens	59.4 ± 1.2 (55.5–66.4) P= 1.98	50.1 ± 1.6 (48–60.4) P= 3.2
	Reversed combination	30.7 ± 0.89 (28.2–36.8) P=2.3	25.1 ± 0.94 (23.2–30.9) P=3.6
2	Georgian varieties of soft wheat x *T. turgidum* var. striatum	54.1 ± 1.8 (48.2–61.6) P= 2.8	40.8 ± 0.78 (38.5–45.2) P= 2.4
	Reversed combination	25.9 ± 1.4 (21.1–32.1) P=4.04	20.9 ± 0.64 (17.6–25.3) P=3.1
3	Georgian varieties of soft wheat x *T. carthlicum* var. stramineum	61.6 ± 1.6 (60.1–65.4) P= 2.5	40.5 ± 1.2 (25.1–58.2) P= 3.1
	Reversed combination	34.5 ± 1.46 (32.7–37.2) P=4.2	28.0 ± 0.9 (13.5–39.7) P=3.5
4	Georgian varieties of soft wheat x *T. dicoccoides* var. arabicum	58.8 ± 1.36 (49.8–60.6) P= 2.44	2.9 ± 0.32 (2.0–5.1) P= 4.7
	Reversed combination	28.4 ± 0.86 (25.5–29.9) P=3.1	2.3 ± 0.11 (1.9–4.9) P=3.1
5	*T. carthlicum* x *T. turgidum*	93.0 ± 1.52 P= 1.6	57.1 ± 1.9 P= 3.3
	Reversed combination	72.4 ± 2.5 P=3.4	36.8 ± 2.0 P=3.3
6	*T. carthlicum* X *T. durum*	91.9 ± 2.1 P= 2.3	53.9 ± 1.7 P= 3.2
	Reversed combination	75.8 ± 2.4 P=3.2	40.5 ± 1.4 P=3.5
7	Georgian varieties of soft wheat x *T. timopheevii*	35.6 ± 1.2 P= 1.7	12.3 ± 1.6 P= 1.9
	Reversed combination	46.3 ± 1.5 P=1.9	24.4 ± 1.9 P=1.7
8	Georgian varieties of soft wheat x *T. zhukovskyi*	40.5 ± 1.9 P= 1.8	20.5 ± 1.9 P= 2.1
	Reversed combination	50.2 ± 2.1 P=2.1	29.5 ± 1.4 P=1.8

is obtained with participation of a resistant variety of soft wheat, or when *T. timopheevii* or *T. Zhukovskyi* are one of the parental forms.

Establishment of regularities according to the plant height, productive tillering, spike length, number of spikelets developed on a spike and number of grains in it, mass of single spike and mass of 1000 grains does not seem possible because of lethal or sublethal combinations obtained as a result of the effect of genes responsible for hybrid necrosis, red hybrid chlorosis and hybrid dwarfness. Heterosis was marked in the inheritance of plant height, productive tillering, spike length and number of spiklets per spike in the plants which survived from the effects of these genetic phenomena, while depression was revealed in the inheritance of such traits as number of grains per spike and mass of 1000 grains.

Heterosis is evident also in the process of inheritance of the content of protein and essential amino acids – lysine and tryptophan – in the first generation of hybrid grains. Level of heterosis is higher when one of the paternal forms while obtaining the hybrid is *T. carthlicum* (Dika). *T. timopheevii* (Chelta Zanduri) and *T. zhukoskyi* (hexaploid Zanduri).

Conclusions

The following has been revealed as a result of study of peculiarities of inheritance of crossability, germination capacity of hybrid grains and survival capacity of plants in combinations obtained as a result of reciprocal crossing of endemic and other species of Georgian wheat with varieties of soft wheat and issues of inheritance of traits of parental forms in the first generation:

1. Endemic and other species of Georgian wheat easily cross with varieties of soft wheat and do not require additional manipulations, but hybrid combinations do differ from each other by the level of this index.

2. Setting of hybrid grains is higher when species with lower number of chromosomes is pollinated with pollen grains derived from species with higher chromosome number.

3. Varieties of Kartli ecotype of soft wheat reveal more isolation in crossing with any of wheat species, while the hybrid varieties of soft wheat belonging to the West Georgian ecotype reveal more closeness.

4. Viability of hybrid plants and productivity is higher when a maternal form with higher chromosome number is pollinated with pollen grains belonging to species with small chromosome number.

5. Survival capacity of hybrid combinations and productivity is higher when soft wheat or endemic species of wheat (*T. carthlicum. T.timopheevii. T. Zhukovskyi. T. georgicum* or *T. macha*) play the role of a maternal plant.

6. Strength and doses of lethal complementary genes contained in the genotype of paternal forms are responsible for the level of viability and productivity of hybrid plants.

7. In the hybrids of the first generation dominant (absence of an awn, downiness, red and black coloration, red color of grain, keratoid consistence of grain, fragility of spike) and recessive traits (presence of an awn, white color, absence of downiness, white color of awn, flour-like consistence) have been established.

8. It has been established in hybrids of the first generation that inheritance of the duration of vegetation period is of intermediate character. Heterosis is expressed in spike length, number of spikelets and productive tillering, protein content of grains, while depression is marked in such indices as number of grains per spike, mass of single spike and mass of 1000 grains.

გენეტიკა და სელექცია

საქართველოს ხორბლის ენდემური სახეობების აბორიგენულ ჯიშებთან შეჯვარებადობა და ნიშან-თვისებები F1-ში

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ნაშრომში ნაჩვენებია, რომ საქართველო კულტურული ხორბლის წარმოშობის, ფორმათა წარმოქმნის და მრავალფეროვნების პირველადი ცენტრია, მსოფლიოს სხვა ქვეყნებს შორის გამოირჩევა ენდემიზმის მაღალი დონით. დასაბუთებულია, რომ საქართველოს ხორბლის უნიკალურმა ენდემურმა სახეობებმა ძალიან დიდი როლი შეასრულეს ***Triticum***-ის გვარის ევოლუციაში და ხორბლის მსოფლიო სელექციაში. მათ საფუძველზე მიღებულია ხორბლის ახალი სახეობები, გვარები, კულტურები და ჯიშები. მათ გენოტიპშია ისეთი გენები, რომლებიც განაპირობებენ სრულიად ახალი ტიპის იმუნური, მაღალხარისხოვანი, ადაპტაციის მაღალი უნარის მქონე, ეკოლოგიურად უსაფრთხო პროდუქციის, მაღალ და მყარმოსავლიანი ჯიშების მიღებას. ნაშრომში განხილულია, საქართველოს ხორბლის ენდემური სახეობების სხვა სახეობებთან და რბილი ხორბლის აბორიგენულ და სელექციურ ჯიშებთან შეჯვარებადობის უნარიანობა, ჰიბრიდული მარცვლების და პირველი თაობის მცენარეთა სიცოცხლისუნარიანობა, პირველი თაობის მცენარეებში მშობლიური ფორმების მორფოლოგიური და სამეურნეო ნიშან-თვისებათა მემკვიდრეობის თავისებურებანი.

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