Advances in Engineering Research, volume 151
International Conference on Smart Solutions for Agriculture (Agro-SMART 2018)

Prospective Study of Source Material for Spring Barley Breeding North-Western Region

Tatiana N. Radyukevich
Federal State Budget Institution
Leningrad research institute for
agricultural science «BELOGORKA»
Leningrad region, Gatchina district
Belogorka, Russian Federation,

Lyubov M. Bondareva
Federal State Budget Institution
Leningrad research institute for
agricultural science «BELOGORKA»
Leningrad region, Gatchina district,
Belogorka, Russian Federation
e-mail: lenniish@mail.ru

Lyudmila I. Kartashea
Federal State Budget Institution
Leningrad research institute for
agricultural science «BELOGORKA»
Leningrad region, Gatchina district,
Belogorka, Russian Federation
e-mail: lenniish@mail.ru

Dmitry A. Danilov
Federal State Budget Institution
Leningrad research institute for
agricultural science «BELOGORKA»
Leningrad region, Gatchina district,
Belogorka, Russian Federation
e-mail: stown200@mail.ru

***Abstract*—The article presents the results of a 3-year study of the varieties from the world collection of the Federal Research Centre of the All-Russian Institute of Plant Genetic Resources named after N.I. Vavilov (VIR) in order to identify sources of economically valuable traits when using them in breeding work. Sources of precocity (6 varieties), of a short stalk (20 varieties), of a long tail (7 varieties), and sources of coarse grains (12 varieties) were identified, and the most harmful fungal diseases of the collection were identified. On the basis of the identified sources, a valuable initial selection material for spring barley is created at Leningrad Research Institute of Agriculture "BELOGORKA".**

Keywords—barley, collection, breeding, speed, sustainability to diseases

I. INTRODUCTION

One of the main grain crops for feed production in Europe is spring barley. There are thousands of cultivated barley landraces and hundreds of cultivars. Cultivars can be classified according to several factors: the number of rows of grains (2-row and 6-row), compactness of spikes, hull adherence (hulled or naked barley), presence or size of awns, growth habit and color [12,17,20,22,24,25,30]. The end-use may also be a way to classify barley. The average yield for barley grain is 2.7 t/ha, but there are large differences among countries starting from yields as high as 8.39 t/ha in Belgium and ending with yields as low as 0.6 t/ha in Morocco and 0.2 t/ha in Lesotho [31].

Barley grain has three major uses: livestock feed, raw material for alcohol and starch production, and food. Barley is of utmost importance for livestock feeding, which accounts for about 85% of barley production. Six-row barleys, which have higher protein content, are a valuable feed ingredient. Two-row barleys contain more starch and less protein and are thus preferred for brewing. Barley with more than 11.5% of protein causes beer cloudiness [5,8,19].

A barley grain is used for the production of alcohol - beer, whisky and ethanol, non-alcoholic beverages, barley tea, breakfast beverages. Food products include starch flour, flakes and pearled barley and it is a staple food in several countries including Morocco, India, China and Ethiopia [8,31]. The by-products of barley grain processing are used as feed: brewer's grains, brewer's yeast, malt culms (barley sprouts and rootlets), barley distillers and solubles, hulls, bran and barley feed the by-product of pearl barley production. Barley forage can be fed to livestock as pasture, hay or silage. Barley straw is also used as fodder for ruminants and as bedding material.

Milk and meat cattle breeding are the main sectors of agricultural production in the North-West region of Russia. The basis for the development of animal breeding and poultry in the region is the creation of a stable high-quality feed base, which is largely formed by concentrated feeds. The basis of these feeds is a grain of local production. The use of own grain ensures a reduction in production costs and an increase in the competitiveness of animal breeding products, allows the use of modern technologies for the preparation of concentrated feeds, such as production of grain-haylage and grain crushing [7,10]. These advanced technologies are widely used in the areas of the North-West of the Russian Federation. For example, in the Leningrad region, about 15% of grain crops are harvested for grain-haylage, up to 50% - for production of crushed grains, and 15% for dry feed grains [15]. Cereals in the North-West

region, in general, are grown for forage purposes. The spring barley is the most important forage culture for this area. The barley occupies 63% of the grain area, oats - 20%, winter and spring wheat - 12%, spring and winter triticale - 5% of the area in the Leningrad region [7].

At the present stage of the development of agriculture, the variety is the most effective and most accessible mean to increase the size and quality of the crop, energy saving, to increase the nutritional value and competitiveness of agricultural production.

The creation of new high-yielding varieties that meet the requirements of modern agricultural production is necessary for the development of the entire agro-industrial complex in Russia.

The purpose of this study is to identify genetic sources of economically valuable features for creation of a promising breeding material of spring barley on the basis of studying the collection varieties of the Federal Research Center of the All-Russian Institute of Plant Genetic Resources named after N.I. Vavilov (VIR)[18].

II. Materials and Method

A comprehensive study of varieties and samples of spring barley *Hordeum vulgare* of the VIR collection on economic-valuable traits was carried out within three years. 107 samples of spring barley were studied in 2015, 84 - in 2016, and 73 - in 2017.

The studied samples included zoned varieties both in the North-West region, and in other regions of Russia, varieties of domestic breeding and foreign countries. Most varieties of barley were varieties from Western Europe (Czech Republic, Germany, France, England), Belarus, Ukraine, the Baltic States (Latvia, Lithuania), Finland, Sweden, Denmark, as well as the USA and Australia [10,12,17,21,24,25]. In addition, varieties and promising breeding lines of the State research enterprise Leningrad research institute for applied agricultural science, Belogorka Russian (Leningrad RIAS «Belogorka»), such as Leningradskiy, Severyanin, Baltika, Murash, Belogorskiy, Karat, L1505, and L1623, were sown in the collection seed-field. Zoned and widely cultivated variety of spring barley Suzdalets was selected by the Agricultural Research Institute of the Central Regions of the Non-Chernozem Zone, and Lenigrandskiy variety was selected by the Leningrad RIAS «Belogorka», which has been zoned in the North-West region since 2009. They were taken as standard varieties. The study of varieties of spring barley on the basis of morphological and economic-biological features was carried out according to the "CMEA international classifier of Hordeum genus", "Methodological guidelines for studying and preserving the world collection of barley and oats" [16,18].

III. Results of Studies

The main direction of breeding work in the Leningrad Research Institute of Agriculture "Belogorka" is breeding for the creation of productive and early-ripe barley varieties.

Barley varieties studied in the collection seed-field mainly belonged to the group of middle-ripe. According to the data for 3 years, 6 early-ripe varieties were identified, among them the majority (5 varieties) are of Russian breeding, including 4 varieties bred by Leningrad Research Institute "Belogorka" (Leningradskiy, Murash, Belogorskiy, and L1505), Tarskii 3 (Omsk region) and a Unari variety of foreign breeding (Finland). The fastest-growing variety of the studied ones was standard variety Leningradskiy (duration of the vegetation period was 79 days, and for standard variety Suzdalets - 88 days according to average data for 3 years) (Table 1). One of the limiting factors for increasing yields in conditions of increased moisture and long daylight is lodging. The lodging leads to a loss of 10 to 50% of the crop, prevents mechanized harvesting, impairs the quality of grain and seeds [1,2,11,13,14,23,28]. The resistance to lodging in cereals is closely related to the height and strength of the straw. Short-stemmed plants, as a rule, are more resistant to lodging According to the results of a 3-year study of collection samples, 20 low-growing varieties (61-70 cm long) and medium-sized (71-80 cm) varieties were identified. These varieties are shorter-stemmed than early-ripe variety Leningradskiy, which is prone to lodging in wet years (the length of the straw is 92 cm) (Table 2).

TABLE I. Sources of the spring barley early ripeness

VIR catalogue No.	Variety sample	Origin	Vegetation period, days			
			2015	*2016*	*2017*	*average*
30314	Suzdalets, st. (nutans)	Russia, Moscow region	86	83	94	88
30975	Leningradskiy st. pallidum	Russia, Leningrad region	78	71	88	79
30593	Tarski 3 (pallidum)	Russia, Omsk region	79	76	90	82
30822	Murash (pallidum)	Russia, Leningrad region	79	75	92	82
22089	Belogorskiy (pall.+ricot)	Russia, Leningrad region	81	75	91	82
30457	Unari (nutans)	Finland	81	79	92	84
	L1505 (pallidum)	Russia, Leningrad region	81	75	91	82

TABLE II. SOURCES OF SHORT-STALK SPRING BARLEY

VIR catalogue No.	Variety sample	Origin	Height of a stem, cm			
			2015	*2016*	*2017*	*aver.*
Species pallidum						
30975	Leningradskiy st.	Russia, Leningrad region	101	78	97	92.0
	L1007-99	Kirov	68	67	80	71.5
Species						
30314	Suzdalets st.	Russia, Moscow region	93	79	85	85.7
31246	Brovar	Belarus	76	74	80	76.6
31241	Quench	Denmark	67	70	75	70.7
31244	Anakin		77	75	80	77.4
31242	J.B. Flavour	Germany	74	69	71	71.3
31245	Posada		73	69	75	72.3
31192	Jenuva		79	77	74	76.7
31179	Radegast	Czech Republic	78	72	75	75.0
31181	Pedant		77	73	80	76.7
31183	Malz		71	72	69	70.6
31184	Ebson		79	71	73	74.3
31186	Respect		74	67	76	72.4
30943	Amulet		73	63	79	71.6
31206	Arbalet	Finland	74	68	78	73.3
31249	Eifel	France	68	63	76	69.0
31250	Pionier		73	65	75	71.0
31296	Olimpic		71	68	71	70.0
31287	April	Russia, Finland	79	76	80	78.3
31297	Cherio	Denmark	73	77	80	76.7
30966	Margret	Germany	74	79	79	77.3

During the study years, the weather during the plumpness and ripening period was rainy and windy. Excessive moistening facilitated the lodging of plants in the plots. Thus, in 2015, 15 samples out of 107 (68%) were resistant to lodging (stability assessment - 7-9 points), in 2016 - 23 samples out of 84 (27.3%) and in 2017 - 25 samples out of 73 (34, 2%) (Table 3). The length of the ear is one of the features that determines the productivity of barley plants. According to the International Classification of Barley Selection Characteristics (1983), most of the varieties under study belong to the group with an average length of the ear (7.1-9.0, 9.1-10.0 cm). A long ear (10.1-11.0, 11.1-12.0 cm) was noted in varieties of Russian breeding Karat and Vladimir. Standard varieties Suzdalets have the length of the ear of 8.6 cm, and variety Leningradskiy - 7.3 cm (Table 4).

The mass of 1000 grains is a feature that determines the yield of a variety.

Weather conditions during the study years (moderately warm weather, sufficient rainfall) contributed to the formation of large grains in barley plants. A very high mass of 1000 grains was noted in varieties Jdumeja (Latvia), Unari (Finland), Amulet (Czech Republic), Vladimir (Russia) and Eifel (France) (table 5).

The evaluation of barley varieties for resistance to the most harmful fungal diseases is of great importance. In recent years, the severity of leaf parasites such as powdery mildew (mushroom Blumeria graminis (DC), net (Pyrenophora teres (Died.)) Drechler and dark-brown (Bipolaris Sorokiniana (Sacc.) Shoemaker blotches. The certain epiphytoties occur at a frequency of once every 3-5 years, while crop losses can reach 25-50% in susceptible varieties [1,2,6,8].

TABLE III. RESISTANCE OF COLLECTION SAMPLES OF BARLEY TO LODGING

Year of study	Number of studied samples	Samples resistant to lodging (score 7-9 points)	
		Number	*%*
2015	107	15	14
2016	84	23	27.3
2017	73	25	34.2

TABLE IV. SOURCES OF LONG EAR IN SPRING BARLEY

VIR catalogue No.	Variety sample	Origin	Length of ear, cm			
			2015	*2016*	*2017*	*aver.*
30314	Suzdalets, st.	Russia, Moscow region	9	8	9	8.6
30975	Leningradskiy st.	Russia, Leningrad region	8	7	7	7.3
30974	Severyanin		10	9	9	9.4
30589	Baltika		10	8	10	9.4
31196	Karat		11	10	11	10.7
30844	Hadzhibey	Russia, Belgorod region	9	10	10	9.7
30981	Vladimir	Russia, Moscow region	10	10	11	10.4
31297	Cherio	Denmark	10	9	9	9.4
31288	Avtograf	Russia, Finland	9	9	10	9.4

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while crop losses can reach 25-50% in susceptible varieties [1,2,6,9].

TABLE V. SOURCES OF LARGE GRAIN IN SPRING BARLEY

VIR catalogue No.	Variety sample	Origin	Weight of 1000 grains			
			2015	*2016*	*2017*	*average*
30314	Suzdalets, st.	Russia, Moscow region	60.5	41.5	54.2	52.0
30975	Leningradskiy st.	Russia, Leningrad region	47.3	35.6	44.1	42.3
30591	Rahat	Russia, Moscow region	63.3	50.8	58.2	57.4
30457	Unari	Finland	67.5	53.5	57.3	59.4
30844	Hadzhibey	Russia, Belgorod region	65.3	46.0	53.4	54.9
	L1623	Russia, Leningrad region	63.4	50.4	54.1	55.9
30922	Jdumeja	Latvia	68.8	55.3	62.5	62.2
30943	Amulet	Czech Republic	63.2	53.8	62.3	59.8
30966	Margret	Germany	62.5	47.8	55.2	55.1
30981	Vladimir	Russia, Moscow region	65.5	57.0	54.6	59.0
31244	Anakin	Denmark	65.7	52.8	55.4	57.9
31249	Eifel	France	67.0	50.4	59.6	59.0
31250	Pionier	France	67.2	45.6	63.8	58.8
30974	Severyanin	Russia, Leningrad region	60.5	51.8	49.6	53.9

According to the agreement on scientific cooperation with the laboratory for study of immunity of plants to diseases of the All-Russian Plant Protection Institute (city of Pushkin), the staff of this laboratory annually assess the varieties of spring barley of the collection seed-field for resistance to leaf blotches.

No varieties immune to the net and dark brown blotches were identified during the study of collection crops of the spring barley during the period 2015-2017. 76.7% to 96.2% of barley samples were characterized by years by the weak lesion (up to 15%) to the net blotch agent, and 14.3 to 93.4% - to the dark-brown blotch (table.6).

In 2016, in the North-West region of the Russian Federation, including in the Leningrad Region, an epiphytoty of dark brown blotch was observed. The lesion of standard varieties Leningradskiy and Suzdalets was 30-50%. The varieties Xanadou, Jenuva, Mauritia (Germany), Malz, Respect (Czech Republic) were characterized by high susceptibility (50-70%) to the pathogen. Against this background, variety Malva (Latvia) was noted; its lesion in the epiphytoty year was 10-15%.

In 2015, the abundance of precipitation under a favorable temperature regime contributed to the epiphytotic development of powdery mildew. The pathogen development was 40-50% on standard varieties. The lesion above the standards (60-80%) was noted in varieties Zenit, Zauralsky 1, Rodnik Prikamye, Variant, Sibiryak, Stepan, Moscovskiy 86 (Russia), Romantik (Ukraine), Saloon (Czech Republic).

TABLE VI. EVALUATION OF SPRING BARLEY VARIETIES FOR RESISTANCE TO LEAF BLOTCHES

Year of study	Number of evaluated samples	Development of disease,%							
		net blotch				*dark brown blotch*			
		up to 15%	% of the total number of samples	30-50%	% of the total number of samples	up to 15%	% of the total number of samples	30-50%	% of the total number of samples
2015	107	103	96.2	4	3.8	100	93.4	7	6.6
2016	84	70	83.4	14	16.6	12	14.3	72	85.7
2017	73	56	76.7	17	23.3	35	47.9	38	52.1

IV. CONCLUSION

As a result of the studies, sources of valuable economic features were identified. The hybridization is annually carried out in the laboratory with active involvement of dedicated sources to create a new promising breeding material. The scope of hybridization is 25-30 of crossing combinations, and the binding of hybrid grains is F_0 - 46.2 to 82.3%. The involvement in the selection process of seed sources with economically valuable traits will allow one to get varieties of spring barley with guaranteed yield.

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