Agronomy Research, vol. 8, № 3, 2010, p. 673-680.

Genetic resources and main directions and results of barley and oat breeding in Russia

I.G. Loskutov

N.I. Vavilov Institute of Plant Industry, St-Petersburg, Russia
e-mail: i.loskutov@vir.nw.ru

Abstract. The oat and barley collections stored at the N.I. Vavilov Institute of Plant Industry (VIR) harbors worldwide genetic diversity. All these vast materials undergo complex studies in the Institute's fields and labs, and the best of them are forwarded to Russia's breeders. Every year dozens of sources and donors produced or identified in the process of study are dispatched to all national breeding centers. As a result, most of the oat cultivars currently listed in the Register of Breeding Achievements of the Russian Federation have been developed on the basis of the VIR collection or with the help of the Institute's researchers.

Key words: Genetic resources, breeding barley and oat, cultivated and wild species.

Introduction

The carefully selected and thoroughly evaluated initial material is of special importance for agricultural crops breeding. For the breeders in the Russian Federation, the main source of such material are the global collections conserved at the N.I.Vavilov Institute of Plant Industry (VIR) (Loskutov, 1999).

The VIR collections accumulate the global cultivar and botanical diversity (Malzev, 1930; Orlov, 1935; Bakhteev, 1953; Knupffer et al., 2003) encompassing over 13 thousand oat and over 20 thousand barley accessions. Collections of the institute keep permanently increasing due to the addition of the most interesting breeding, genetic and botanical material from the main centers of origin and diversity of these crops, from the countries which demonstrate a high level of research in the sphere of breeding and diverse utilization of the crops. To this end, researchers of the respective department keep a fixed attention on the achievements in breeding and genetics in the world (Loskutov, 2007; 2009).

Theoretical investigations currently underway at the Department of Genetic Resources of Oat, Rye and Barley are concentrated on the development of methods of efficient utilization of the selected germplasm and on revealing regularities in variation and inheritance of the main traits of importance for breeding (the Cultivated Flora, 1990; 1994). The complex field evaluation is accompanied by the studies performed by the methodological laboratories of VIR and aimed at selecting valuable oat and barley germplasm for solving urgent breeding problems in various regions of the vast country. The research achievements and the available initial material facilitate solving such problems in barley and oat breeding as resistance to the main diseases, earliness, short stem, drought resistance, grain quality (in terms of protein, lysine, fat, individual fatty acids, starch, antioxidants, etc. composition) and grain productivity (Trofimovskaya, 1972; Loskutov, 2007; Loskutov & Rines).

Results and discussion

Genetic stock collections of oat and barley have been composed for solving the main tasks of breeding at the state-of-the-art level, as well as for identifying and localizing the newly revealed genes. For oats, such a collection is composed of cultivars, cultivated lines and wild species with one or more identified gene governing various morphological, agrobiological, biochemical and other traits. The greater part of the collection is represented by accessions with the identified genes controlling short stem character, photoperiodic response, and with the most important genes of resistance to powdery mildew, crown and stem rusts, and to smut species. At present, the oat genetic collection at VIR includes over 600 accessions belonging to cultivated species *A. sativa, A. byzantina, A. strigosa* and *A. abyssinica* and to wild *A. sterilis, A. barbata* and *A. magna* with over 200 identified genes controlling various morphological, physiological, biochemical and other traits (Genetics of cultivated plants, 1988).

The genetic stock collection of barley includes the lines with morphological marker traits localized on 7 chromosomes (65 accessions), lines with male sterility (87 accessions), disease-resistant lines (65 образцов), testers with the identified genes and accessions with known genes that are of interest for breeding purposes (400 accessions). The availability of a wide diversity of cultivars with the same alleles allows breeders from different zones of Russia to select appropriate initial material for breeding oat and barley

(Genetics of cultivated plants, 1986).

Besides creation of genetic stock collections, the main task of the Department is the complex study of the collected germplasm and identification of sources and donors of the economically important traits for breeding purposes. The prolonged study of the oat collection, a large number of early local and breeding forms originating from different regions of oat cultivation have been identified among *A. sativa* and *A. byzantina* accessions. Considerable variation of duration of different periods in plant development is characteristic at the level of a species of some wild forms. The most important factors influencing duration of the vegetative period of a plant, and especially the first half of the period, are the daylight duration and the temperature regime. The results of long-term studies performed together with the Department of Plant Physiology of VIR have demonstrated differences in response to photoperiod and vernalization.

The problem of dwarfness is closely linked to the problem of lodging resistance in oat, the latter occupying a special place among the breeding objectives for this crop. This problem attracts a special attention because of the plant habitus features and high windage of the panicle. The investigations of recent years have identified some perspective forms which may be used as sources combining dwarfness with high grain yield per panicle and good grain quality. Hybridization and multistage selections have yielded some stable, productive forms which transfer the semi-dwarf stem trait in further crosses. The work has resulted in creation of 15 oat donors which are the donors of semi-dwarfness and lodging resistance.

A complex phytopathological evaluation of the entire specific diversity of the *Avena* genus facilitates selection and utilization of new sources and donors of resistance thus broadening genetic basis of the new created oat cultivars. Sources of resistance to the main oat pathogens and pests, among which are crown and stem rusts, various leaf blights, smuts and *Fusarium* fungi have been found for different regions of the country. Numerous accessions of cultivated species and especially forms of wild oats have been identified as possessing a high degree of resistance.

From the point of view of nutritional and fodder qualities, biochemical characteristics of oat grain are of the highest importance. These are the protein content and amino acid composition, oil content and fatty acid composition. Recently, the list of biochemical component determining high nutritional value of oats has been extended by including β-glucans, tokopherols, sterols, avenanthramides and other components. At present, this trend in studies of the collection is the most promising one that has resulted in the identification of interesting initial material (Loskutov, 2007; Loskutov& Rines, 2010).

In the first place, success in barley breeding around the globe is achieved thanks to high ecological plasticity of this crop and high adaptability to local cultivation conditions, which are realized due to barley earliness. The heading time is determined mainly by three factors, namely the genes governing the type of development, insensitivity to the photoperiod, and earliness proper. At present, researchers of the Department pay the major attention to the first factor, it being among the leading ones that control the earliness of heading in barley. Selection of appropriate cultivars with the optimal rate of development is carried out for each ecogeographic region because in certain zones the use of potentially late genotypes does not always mean obtaining the highest yield, while early cultivars can realize their potential to a better degree under these conditions and ensure secure yields. Investigation of barley genetic diversity from the point of view of the rate of development may significantly reduce the role of the uncontrolled temperature and light factors, increase cultivars adaptability and, finally, achieve high stable yield.

A special attention in the work with the barley collection is paid to the complex evaluation of the economically important traits of accessions which makes it possible to identify genotypes meeting various breeding requirements. The selected accessions are supplied to breeding institutions and successfully used in breeding high-productive cultivars.

Development of barley cultivars insensitive to diseases and pests is one of important breeding objectives. According to the global practice, their cultivation is the cheapest and ecologically safe approach to control harmful organisms. The screening of the collection for resistance to diseases and pests is carried out jointly with the Department of Immunity. Several cultivars bred by the Agricultural Research Institute for the Regions of the Non-Black Soil Belt (ARI NBSB) of Russia and featuring high productivity, high brewing quality and other economically important traits have been identified among those possessing resistance to two smut species.

Another priority trend related to the global warming is the investigation of acidity tolerance. High acidity of soils has a negative impact on plants growth and development. The most promising way is the creation of cultivars that would be tolerant to soil acidity, as the application of only agrotechnical measures is quite costly, yields a transitive effect and has a harmful influence on the environment in the regions. A screening of barley accessions from Russia, CIS countries, Baltic states, Scandinavia, Western Europe and Japan has found sources of tolerance.

In addition to such traditional qualitative characteristics of barley grain as the content of protein, oil and starch, the content of different types of polysaccharides, vitamins and antioxidants acquires the highest importance. The latter group of substances includes β-glucans, tokopherols and some others. Such investigations are quite promising and we seek opportunities to perform them with other institutions in Russia and abroad.

In recent years, much attention is paid to studies and creation of naked oat and barley cultivars. These forms show better grain quality, but possess a series of negative traits. The Department is involved in the identification of initial material that will be promising within the framework of the above activities and supplies Russian breeding centers with it.

All the oat and barley germplasm material selected and created in the course of the work performed by the Department is forwarded to over 30 breeding centers in the Russian Federation for utilization in various breeding programs. As a result, the majority of oat and barley cultivars (90% according to some sources) included in the State Register of Breeding Achievements Approved for Utilization have been created on the basis of germplasm from the VIR collections or jointly with VIR researchers.

At present (2010), the State Register of Breeding Achievements Approved for Utilization in Russia includes 91 spring and 4 winter oat cultivars (among which 12 are foreign cultivars, 1 is from Ukraine, 2 are Byelorussian and 80 are Russian) (State Commission… Avena sativa).

Winter oat breeding in Russia is carried out only in the Adygean Agricultural Research Institute that has produced all 4 commercial cultivars: Podgorny and Mezmai, Guzeripl and Verny. All cultivars are productive, resistant to diseases and display good winter hardiness, as prolonged periods with negative temperatures are quite frequent in this region.

In terms of the longest period of cultivation in Russia, the first place is shared by a Swedish cv. Guldregn created at the Swalof Breeding Station (Sweden) in 1904 and commercialized in the USSR in 1929, and a Russian cv. Narysmky 943 bred at the Narymsk Breeding Station, the oldest in Russia (now the Narym Department of Breeding and Seed Growing of the Siberian Research Institute of Agriculture and Peat) and commercialized in 1973. In the USSR, the latter cultivar occupied over 1 mln ha of the total land under this crop. Also, a Russian cv. Taezhnik (Narymsk Breeding Station), Ukrainian cv. Chernigovsky 83 (Chernigov Breeding Station) and two foreign cultivars – Selma (Sweden) and Astor (the Netherlands) – were commercialized in Russia in the 1970's and are still cultivated in this country. The majority of cultivars in the Register were included into it during the period from 1990 through 2007.

The cultivar Uspekh, the first naked oat cultivar in the USSR, was commercialized in 1981. It was produced at the Uzbek Husbandry Research Institute jointly with VIR. After the disintegration of the USSR, this cultivar stayed outside Russia and only in 2000 the first Russian naked oat cv. Tyumensky golozerny (bred by the Agricultural Research Institute for the Northern Transurals) was commercialized. Other naked oat cultivars, namely Levsha (bred jointly by the Kemerovo Agricultural Research Institute (KemARI) and VIR) was approved for utilization in 2005, cv. Vyatsky (created by the Agricultural Research Institute for the Northeast (ARINE) was approved in 2007, and cv. Golets (the Krasnoyarsk Agricultural Research Institute) and cv. Sibirsky golozerny (the Siberian Agricultural Research Institute (SibARI) were approved in 2008.

The most productive breeding centers in Russia are the ARI NBSB and ARINE. Fifteen oat cultivars presently listed in the Register have been bred at the ARI NBSB jointly with the Ulyanovsk Agricultural Research Institute (UlARI) and other breeding institutions. Quite a success is the ARINE, that together with its Falenskaya Breeding Station has released 10 commercial oat cultivars. Seven cultivars have been developed at the Narymsk Breeding Station (some of them jointly with other institutions), 6 cultivars have been released by the SibARI and 4 more – by the Buryat Agricultural Research Institute. By now, approval has been granted for the utilization of cultivars bred by the following institutions (3 cultivars per each organization): SibARI, Altai ARI, KemARI, Tulun Breeding Station and VIR. It is necessary to mention the great contribution to the creation of new oat cultivars made by the UlARI. Though it is not involved in hybridization activities, it actively participates at other stages of breeding programs and further performs initial seed growing for the released cultivars.

When speaking about characteristics of the approved cultivars, high degree of adaptability of some of them should be noted. In Russia in 2010, the most widely spread oat cultivar is Skakun (ARI NBSB), which is cultivated in 9 out of 12 regions of the territory of Russian Federation. This cultivar, characterized by high-yield and high grain quality, is on the List of the Valuable Quality Cultivars. Cultivar Konkur (ARI NBSB and UlARI) has been commercialized in 7 regions of Russian Federation, two cultivars, namely Borets, and Dens (ARINE) - in 6 regions; two cultivars – Ulov (ARI NBSB) and Tyumensky golozerny (Tyumen ARI) – in 5 regions, and such cultivars as Drug, Kozyr (ARI NBSB), Argamak and Faust (ARINE) have been commercialized in 4 regions. All the named cultivars are highly productive, resistant to diseases and,

with exception for Dens and Faust, have been put on the List of the Valuable Quality Cultivars. The cultivars Privet, Lev, Yakov (ARI NBSB), Talisman (Narym Breeding Station), Kirovets, Krechet (ARINE), Fakir (Falenskaya Breeding Station) and Allyur (UlARI) have been commercialized in 3 regions.

At presen (2010)t, the State Register of Breeding Achievements Approved for Utilization numbers 162 spring and 26 winter barley cultivars. The cultivars commercialized in Russia include 22 spring and 2 foreign winter cultivar, 6 Ukrainian and 1 Byelorussian cultivars. So, Russian breeders have created the total of 157 barley cultivars, 4 of which are naked barley cultivars (State Commission… Hordeum vulgare).

Significant work in the sphere of winter barley breeding is done at the Krasnodar ARI (12 cultivars), at the All-Russian Research Institute of Cereal Crops (ARRICC, 4 cultivars), at the Stavropol ARI (2 cultivars) and other institutions. All winter barleys are cultivated in the North Caucasus region only. Almost all of them are six-row barleys used mostly as forage.

Some spring barley cultivars currently cultivated in Russia were commercialized in the times of the USSR, back in the 1960's. For instance, these are Tammi (Finland) and Varde (Norway); 5 more cultivars were commercialized in the 1970's and 20 more – in the 1980's. Among them, The cultivar worth mentioning among them is Odessky 100 (Ukraine): it was commercialized in the USSR in 1984 and now it occupies the largest areas in Russia among other spring barleys. The majority of modern commercial spring barley cultivars (120 all in all) have been cultivated for less than 15 years.

The State Register of Breeding Achievements Approved for Utilization contains 3 naked barley cultivars: Omsky golozerny 1 (Omsk ARI) since 2004, Oskar (Krasnoyarsk ARI) since 2007, Omsky golozerny 2 (Omsk ARI) since 2008 and Nudum 95 (Skiff) since 2010.

In terms of the numbers of commercialized spring barley cultivars and areas occupied by them, the first place is shared by the ARI NBSB and ARRICC, which have created either individually or jointly with other breeding institutions 9 cultivars each. In different years, breeding activities have successfully resulted in the release of new cultivars at SibARI (8 cultivars), ARINE (6), Siberian Research Institute of Plant Industry and Breeding (6), and Krasnodar ARI (5 cultivars).

The most widely distributed barley cultivar in Russia is cv. Odessky 100 (Plant Breeding and Genetics Institute (PBGI), Ukraine) which is cultivated in 7 out of 12 regions of Russian Federation. This high-yielding cultivar with high grain qualities has been put on the List of Brewing and Valuable Quality Cultivars. The cultivar Dina (ARINE) has been commercialized in 6 regions, the cultivars, namely Preriya (PBGI) and Elf (ARI NBSB), Zevs (Belselect), Nur (ARI NBSB), Priazovsky 9 (All-Russian Research Institute of Grain Legumes and Groat Crops) in 5 regions, and several cultivars, i.e., Acha (SibARI), Bios 1, Raushan (ARI NBSB), Gonar (Belarus), Veles (Belselect), Odessky 115 (Ukraine) and a German cultivar Annabel – in 4 regions. Most of these are highly productive cultivars from the List of Valuable Quality Cultivars.

Conclusion

All the cultivars of oat and barley listed in the State Register of Breeding Achievements Approved for Utilization in Russian Federation (most of which were created using germplasm from the VIR collections) are the most productive ones and are better adapted to conditions of the regions they were intended for. Many of them are high-quality cultivars resistant to the main diseases because either their pedigrees include germplasm from the VIR global collections, or their testing had been carried out using the best cultivars from around the globe in the VIR collections as the standard material.

At present, the requirements of agricultural production are changing, and the material needed for creating new cultivars that should be in the first place qualitatively diverse rather than productive can be found in the VIR collections which contain the material required for creating cultivars of both naked and hulled oat and barley that will be used for producing food with high dietary qualities. Many sources conserved in the collections display tolerance to a series of abiotic factors and possess resistance to the main diseases and pests.

The unique collections at VIR have concentrated the entire global diversity of local and bred varieties and, being the collections studied most fully among similar collections elsewhere in the world, is still the richest source of germplasm with traits of breeding importance for both national and foreign breeders.

References

1. Bakhteev, F. Kh. 1953. *Problem of ecology, phylogeny and breeding of barley*. Nauka, M.-L. 218 pp. (in Russian).
2. *Genetic of cultivated plant. Wheat, barley, rye.* 1986. Nauka, L. 264 pp. (in Russian).
3. *Genetic of cultivated plant. Maize, cereals, oat.* 1988. Nauka, L. 276 pp. (in Russian).
4. *Cultivated flora of the USSR. Barley.* 1990. 2-ed. V. 2. Part 2. Kolos, L. 421 pp. (in Russian).
5. *Cultivated flora. Oat.* 1994. 2-td. V. 2. Part 3. Kolos, M. 367 pp. (in Russian).
6. Knupffer, H., Terentyeva, I., Hammer, K., Kovaleva, O., & Sato, K. 2003. Ecogeographical diversity – a Vavilovian approach. In von Bothmer, R., van Hintum, Th., Knupffer, H. & Sato, K. (eds): *Diversity in barley (Hordeum vulgare). Development in plant genetics and breeding.* V. 7. pp. 53-76
7. Loskutov, I. G. 1999. *Vavilov and his Institute. A history of the world collection of plant resources in Russia.* IPGRI. Rome. Italy. 190 pp.
8. Loskutov, I. G. 2007. *Oat* (*Avena* L.). *Distribution, taxonomy, evolution and breeding value.* VIR. S-Pb. 336 pp. (in Russian).
9. Loskutov, I. G. 2009. *The history of the world collection of plant genetic resources in Russia.* VIR. S-Pb. 294 pp.
10. Loskutov, I. G. & Rines, H. 2010. *Avena* L. In Kole, C. (ed.): *Wild Crop Relatives: Genomic & Breeding Resources.* Springer, Heidelberg, Berlin, New York. 160 pp.
11. Malzev, A. I. 1930. *Wild and Cutivated oats. Sectio Euavena Griseb.* Works of Applied Botany and Plant Breeding. Supplement № 38. L. 522 pp. (in Russian).
12. Orlov, A. A. 1935. *Barley*. M.-L. 220 pp. (in Russian).
13. State Commission of Russian Federation for Selection Achievements Test and Protection, Avena sativa L. http://www.gossort.com/reestr/ree_13.html#14 (in Russian).
14. State Commission of Russian Federation for Selection Achievements Test and Protection, Hordeum vulgare L. http://www.gossort.com/reestr/ree_31.html#12 (in Russian).
15. Trofimovskaya, A. Ya. 1972. *Barley. (Evolution, taxonomy, breeding).* Kolos, L. 296 pp. (in Russian).