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Mini Review

# GENETIC DIVERSITY BARLEY AND OATS OF N.I. VAVILOV ALL-RUSSIAN RESEARCH INSTITUTE OF PLANT INDUSTRY COLLECTIONS FOR BREEDING

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*The paper summarises long-term data on the collection of cereal forage crops (barley, oat) studied under diverse conditions at experimental stations of the N. I. Vavilov All-Russian Research Institute of Plant Industry. The selected sources of economically important traits that can be used in cereal forages breeding are presented.*

**Key words:** *barley, oat, sources, donors, economically important traits.*

## INTRODUCTION

Creation of new agricultural crop cultivars possessing a complex of important traits, high yielding ability and product quality under different environmental conditions requires well-studied initial material. The problem of selecting the most promising parental forms for crossing from the available genetic diversity of crop plants still remains one of the most difficult and responsible issues in the breeding process.

Cereal forage crop breeding is mainly aimed at raising cultivar grain productivity. Also, duration of the vegetation period of a plant is directly linked with grain yield, its quality and seed sowing qualities. Therefore, in terms of productivity, the mid-early and mid-season cultivars of grain forage crops would be the best in terms of productivity. A potentially high grain yield of agricultural crops should be combined with other economically important traits and resistance to biotic and abiotic factors (Lukyanova *et al*., 1990; Rodionova *et al*., 1994). Diseases not only suppress plants and reduce the size of grains and yields per unit area, but also deteriorate the yield quality through the accumulation of pathogen waste products. Mycotoxins decrease the cost and consumption properties of oat and barley grain and adversely influence human and animal health. The problem of creating cultivars resistant to main diseases becomes of primary importance, since it is the safest way of disease control. Only the availability of adequate initial material will make it possible to successfully solve these and the newly arising problems in breeding. Identification of sources of the main economically important traits is one of the tasks of studying the global diversity of barley and oat accumulated in collections of the Department of Oat, Rye and Barley Genetic Resources at the N.I. Vavilov All-Russian Research Institute of Plant Industry (VIR) (Loskutov, 2007: Loskutov *et al*., 2007).

Collections of grain forage crops at the Vavilov Institute of Plant Industry serve as the main source providing new initial material to breeding programmes aimed at creating new cultivars. The long-term efforts exerted to collect the global diversity at the Institute have resulted in barley and oat collections that are among the largest in Europe. They number about 18000 accessions of barley and over 12000 oat accessions of different geographical origin (Loskutov, 2009; Loskutov and Rines, 2011).

## AGRONOMICAL TRAITS

Studies of the grain forage crops collections are centred on the complex analysis of accessions concerning the main economically important traits and are aimed at the identification of sources and donors of the traits employing VIR guidances (Lukyanova *et al*., 1973; Loskutov *et al*., 2012). The resulting accessions are supplied to the breeding centres where they are successfully used in breeding of new grain forage crop cultivars.

The barley and oat collections of VIR are studied in field conditions at experimental stations of the Institute, most of which are located in the main zones of agricultural crop cultivation (Loskutov and Kovaleva, 2007).

The Department of Oat, Rye and Barley Genetic Resources of VIR widely applies the methods of the initial material joint study to meet necessities of common and new trends in breeding that take shape due to global climatic and phytopa-

thological changes and due to new quality demands in grain processing for food and forage (Loskutov, 1999; 2009). Researchers from the Department carry out their investigations in close cooperation with their colleagues from the VIR departments of Biochemistry and Molecular Biology, Plant Physiology, Genetics and from the Laboratory of Plant Immunity. Also, cooperation with other Russian and foreign research partner at the Institutes is given much attention when seeking for quality scientific results (Loskutov, 2007: Loskutov *et al*., 2007).

The staff of VIR has recently performed a large number of systematic studies of the newly acquired global crop diversity. A versatile analysis of this new material applying all the available methods resulted in the identification of new sources for all of the studied economically important traits.

An extensive interest in genetic studies of barley and oat has provided a basis for the establishment at VIR of genetic stocks collections comprised of cultivars, cultivated lines and wild species with one or more identified genes governing different morphological, agrobiological, biochemical and other traits. The greater part of the collection is represented by accessions carrying the genes of resistance to various diseases (Loskutov *et al*., 1997).

The most important factors influencing duration of the vegetation period of a plant, especially its first part, are light, day duration and temperature regime. The results of long-term studies performed together with the Department of Plant Physiology of VIR have discovered a variety of responses to photoperiod and vernalisation (Tables 1 and 2). Among the recently identified barley and oat accessions that were insensitive to photoperiod were forms from the American continents (Koshkin *et al*., 2010, Loskutov, 2007, Loskutov *et al*., 2007).

The issue of dwarfness is closely linked to the problem of lodging resistance in cereals, and occupies a special place among the breeding objectives for these crops. Investigations of the oat genetic collection performed in recent years have identified accessions that combine semi-dwarf with a high grain productivity of the panicle and good grain quality, and can be recommended for use in breeding (Loskutov, 2007; Loskutov *et al*., 2007; Loskutov, 2010).

Table 1

CHARACTERISTICS OF OAT ACCESSIONS FOR DAY LENGTH INSENSITIVE (Cph), 2012

| No. cata-logue VIR | Origin | Name of variety | Period germination –heading, days | | $T_2$–$T_1$ | Cph |
|---|---|---|---|---|---|---|
| | | | long day, $T_1$ | short day, $T_2$ | | |
| 12230 | Mexico | Chihuahua. st | 38.5 ±± 0.81 | 47.3 ± 0.42 | 8.8 | 1.23 |
| 7751 | Turkey | Local | 37.4 ± 0.82 | 43.4 ± 0.67 | 6.0 | 1.16 |
| 11207 | USA | Burnett | 41.3 ± 1.04 | 56.3 ± 5.82 | 15.0 | 1.36 |
| 11801 | Peru | D 95 E $P_2$ | 40.2 ± 1.45 | 52.3 ± 2.19 | 12.1 | 1.30 |
| 12235 | -"- | Desnuda | 40.3 ± 0.56 | 76.4 ± 9.58 | 36.1 | 1.90 |
| 12614 | Ethiopia | IAR 376 | 41.6 ± 0.76 | 62.1 ± 3.56 | 20.5 | 1.49 |
| 13467 | Mexico | HUA "S"- 4 | 41.1 ± 0.46 | 65.9 ± 5.47 | 24.8 | 1.60 |
| 15153 | USA | B 525 - 336 | 38.8 ± 0.61 | 48.5 ± 0.68 | 9.7 | 1.25 |
| 15216 | -"- | P. T. 629063 | 38.7 ± 0.26 | 48.9 ± 0.52 | 10.2 | 1.26 |
| 15257 | -"- | PA 7836 - 416 | 41.2 ± 0.20 | 66.8 ± 5.50 | 25.6 | 1.62 |
| 15258 | -"- | PA 7836 - 2701 | 38.8 ± 0.20 | 71.9 ± 6.68 | 33.1 | 1.85 |
| 15262 | -"- | PA 7967 - 3145 | 38.4 ± 1.46 | 49.2 ± 2.45 | 10.8 | 1.28 |
| 15267 | -"- | IN 09201 | 37.7 ± 0.40 | 48.8 ± 0.49 | 11.1 | 1.29 |

Table 2

CHARACTERISTICS OF BARLEY ACCESSIONS FOR DAY LENGTH INSENSITIVE (Cph), 2012

| No. cata-logue VIR | Origin | Name of variety | Period germination –heading, days | | $T_2$–$T_1$ | Cph |
|---|---|---|---|---|---|---|
| | | | long day, $T_1$ | short day, $T_2$ | | |
| 18095 | Hungary | Bankuti Korai, st | 38.6 ± 0.54 | 38.3 ± 0.92 | -0.3 | 1.00 |
| 19354 | Sweden | Marii | 43.7 ± 0.96 | 44.9 ± 0.77 | 1.2 | 1.03 |
| 30749 | Russia | Impuls 90 | 41.7 ± 0.47 | 41.8 ± 0.49 | 0.1 | 1.00 |
| 21799 | Australia | Weeah | 37.1 ± 1.29 | 42.2 ± 0.36 | 5.1 | 1.14 |
| 23351 | -"- | Australische | 36.4 ± 0.75 | 45.1 ± 1.21 | 8.7 | 1.24 |
| 29836 | Russia | Gandvig | 47.0 ± 0.65 | 60.3 ± 2.92 | 13.3 | 1.28 |
| 29808 | -"- | Kornet | 47.1 ± 0.77 | 65.2 ± 2.67 | 18.1 | 1.38 |
| 27563 | Finland | Jo 1310 | 50.6 ± 1.18 | 67.3 ± 2.85 | 16.7 | 1.33 |
| 30173 | Canada | Buch | 47.5 ± 1.11 | 60.8 ± 2.92 | 13.3 | 1.28 |
| 30265 | -"- | Sumko | 45.9 ± 0.18 | 66.5 ± 2.13 | 20.6 | 1.45 |

Table 3

LARGE-SIZE GRAIN OAT ACCESSIONS, LENINGRAD REGION, 2008-12.

| No. cata-logue VIR | Origin | Name of varieties | Vegetetive period, days | 1000 grain weight, g | Weight of grains $1m^2$ | |
|---|---|---|---|---|---|---|
| | | | | | g | % of standard |
| 2008–2010 | | | | | | |
| 14897 | USA | IL 2815 | 81.3 ± 3.3 | 54.7 ± 4.7 | 440.0 ± 150.2 | 81.1 |
| 14898 | USA | IL 2838 | 82.3 ± 5.1 | 52.3 ± 5.1 | 330.0 ± 157.3 | 60.4 |
| 2009–2011 | | | | | | |
| 14921 | Chine | Y4 | 84.0 ± 12.8 | 58.0 ± 5.8 | 193.3 ± 151.1 | 34.3 |
| 14916 | Chine | AC Pinnacle | 93.3 ± 2.4 | 54.5 ± 5.6 | 335.0 ± 155.8 | 61.2 |
| 14917 | Canada | AC Ronald | 105.0 ± 2.8 | 55.8 ± 9.2 | 430.0 ± 154.9 | 77.1 |
| 2010–2012 | | | | | | |
| 14988 | Canada | OA 313 | 79.7 ± 4.6 | 63.5 ± 9.6 | 513.3 ± 196.3 | 86.9 |
| 14989 | Canada | ĪĄ 338 | 83.7 ± 6.6 | 56.6 ± 6.8 | 428.3 ± 159.8 | 69.5 |
| 14990 | Canada | ĪĄ 272 | 81.0 ± 9.7 | 59.4 ± 9.1 | 408.3 ± 158.9 | 62.9 |
| 14991 | Canada | ĪĄ 309 | 81.0 ± 4.2 | 62.9 ± 8.2 | 366.7 ± 157.9 | 57.8 |

Plant productivity is composed of several elements, namely, the number of spikelets and grain per spike or panicle, grain mass per ear or panicle, grain mass per plant, and 1000-grain weight (Table 3). Selected cultivars have been found to have high ear or panicle productivity. The accessions identified for their high 1000-grain weight showed a value over 50 g (Loskutov and Kovaleva, 2011; Smirnova and Loskutov, 2011).

The main character grain weight per area unit is a complex index of productivity that significantly varies depending on the growing conditions and cultivar peculiarities (Smirnova and Loskutov, 2011).

## DISEASE RESISTANCE

A complex phytopathological evaluation of all the specific diversity of *Avena* facilitated identification of new sources and donors of resistance that can be used for broadening the genetic basis of newly created oat and barley cultivars. A strong natural infectious background allows to evaluate resistance of accessions to diseases in field conditions. Crown rust affects oat crops each year during the ear formation–ripening stage. Screening in the field has identified a set of barley accessions that displayed resistance under strong infectious stress. A study of the barley collection resulted in the identification of a series of sources of complex resistance to loose and covered smuts. Helminthosporium blight is known to annually affect oat and barley crops to a varying degree. Barley yellow dwarf virus (BYDV) is a very harmful disease that can lead to total death of plants (Loskutov, 2007; Loskutov and Kovaleva, 2007; Loskutov *et al*., 2007; Loskutov and Kovaleva, 2011).

Together with the All-Russian Institute of Plant Protection (VIZR, Russia) and American colleagues from the University of Minnesota (USA) sources of resistance to the most harmful strain of stem rust (Ug99) have been selected from commercialised barley cultivars (Loskutov and Kovaleva, 2011).

Joint investigations of spring barley performed together with American colleagues from the University of Minnesota and of oat performed together with VIZR (Russia) resulted in the identification of sources of grain resistance to *Fusarium* Head Blight and mycotoxin contamination in caryopses within both crops. It has been found that the highest degree of resistance is displayed by naked barleys and oats, but single resistant accessions have also been identified among hulled barleys and oats. The most promising in terms of multicomponent resistance to FHB were found to be oat landraces originating from the Far East of Russia and Asia continent, and resistance to *Fusarium* infection has been found in productive naked oat and barley cultivars (Dahl *et al*., 2009; Gavrilova *et al*., 2011).

## QUALITY COMPONENTS

Due attention is paid to the study of traditional biochemical parameters. A study of a set of barleys performed together with the Department of Biochemistry and Molecular Biology of VIR has identified high-protein accessions from Uzbekistan, Tajikistan, Iran, Afghanistan, India and Ethiopia (Batakova *et al*., 2010).

The most important biochemical components that increase nutritive value of oat include protein, fats, β-glucans, tocopherols, sterols and other components. At present, this trend in studies of the collection is the most promising one. A set of oat cultivars has been analysed for oil content in the caryopsis and its fatty acid composition. This work was conducted together with the Department of Biochemistry and Molecular Biology of VIR. Some accessions had over 7% of oil in the caryopsis; these were some local naked oats from China, Mongolia, Great Britain and Russia, and several hulled oat accessions from different countries. Regarding fatty acid composition, it should be noted that almost all studied accessions had a level of oleic acid content as high as that in sunflower. It was above 40% in some accessions from China, Spain, Great Britain and Russia. Also, a high content of palmitic, oleic and linoleic acids was demon-

strated by cultivars of naked oat (Loskutov *et al*., 2007; Loskutov, 2010).

Some accessions of spring naked barley have been analyzed for β-glucans content. This work, performed together with the Baltika Brewery Company (St-Petersburg, Russia), has shown that two-row barleys had a content of this component that was on average 1.5 times higher than in six-row barleys. Also, joint investigations with the Protein+ Company have resulted in the identification of sources of β-glucan, a non-starch polysaccharide, in oat accessions. Barley and oat with the above-mentioned high quality values can be effectively used in the production of combined feeds, as well as in the food industry, especially for dietary food manufacturing (Batakova *et al*., 2010; Loskutov and Kovaleva, 2011).

## CONCLUSIONS

The complex field evaluation combined with the analysis performed together with methodological laboratories of VIR makes it possible to select valuable genetic material required for solving burning issues of breeding in different regions of the country.

In summary, collections of cereal forages at VIR serve as the main source of initial material required to meet the needs of the main trends in breeding of said crops. The identified barley and oat sources have been sent to over 25 breeding centres in the Russian Federation for breeding new productive cultivars of cereal forages.

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Sniegtas ziņas par miežu un kviešu paraugiem no N. Vavilova Viskrievijas Augkopības institūta kolekcijas, kuri būtu izmantojami šo augu ekonomiski svarīgu pazīmju selekcijā.