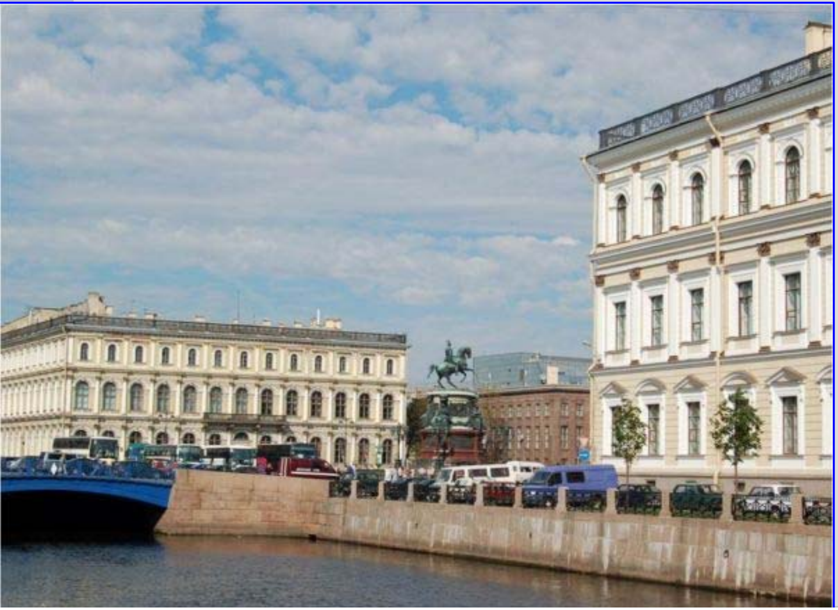
N.I.Vavilov Institute of Plant Industry, St-Petersburg, Russia

Avena genetic resources for oat breeding



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N.I.Vavilov Institute of Plant Industry

has major objectives:

- collecting
- characterization and evaluation
- storage
- using

VIR

1894 - 2014

N.I.Vavilov Institute of Plant Industry is harbored one of the largest collection of **4** cultivated and **22** wild oat species.

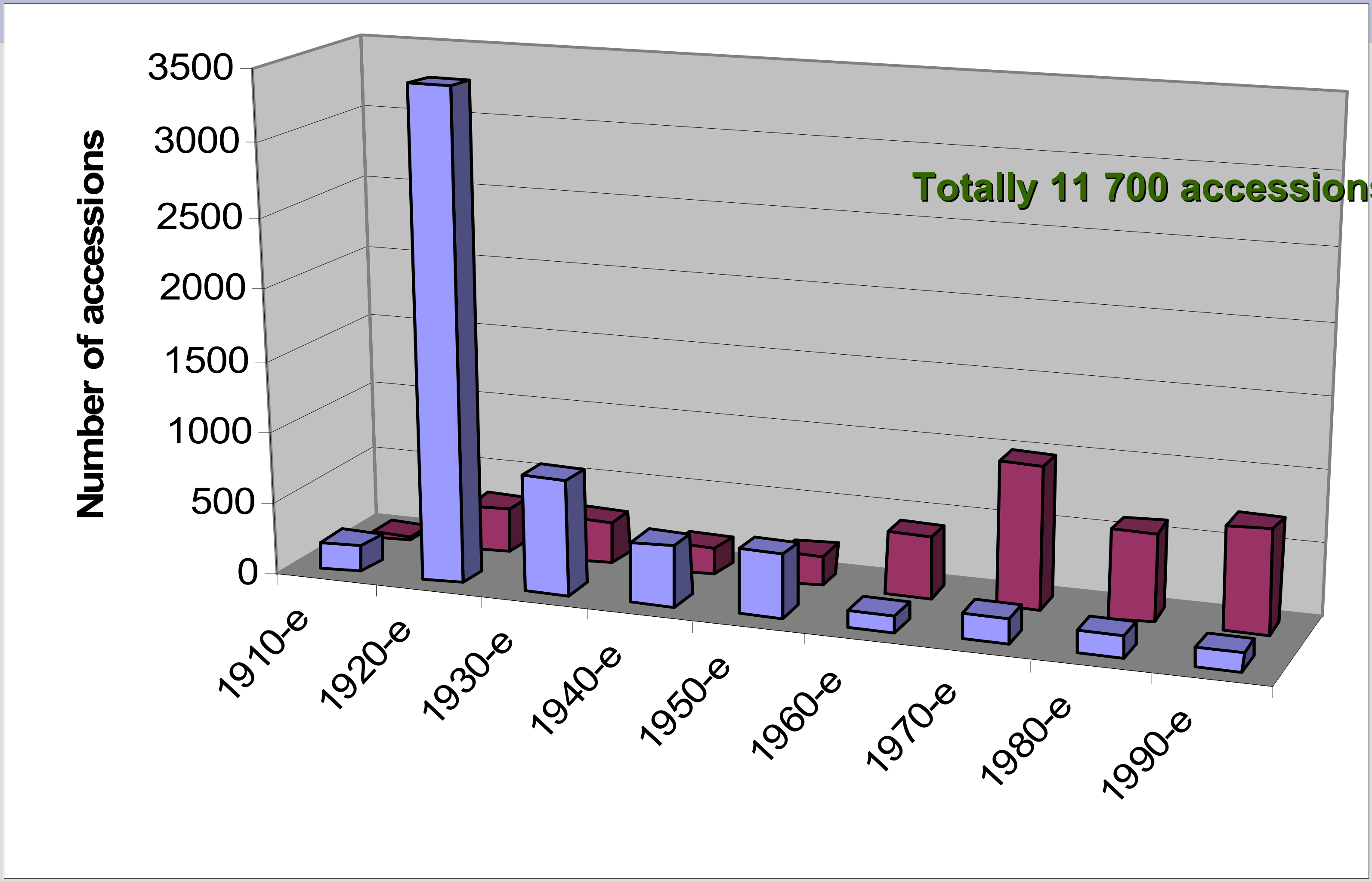
There are more than **11 700** cultivated and **2 000** wild oat accessions there.

It presents global genetic diversity of ***Avena*** genera with wide variability of morphological, agronomical and biochemical characters for oat breeding.

Some results of the evaluation are presented in:

- Loskutov I.G., Rines H.W. *AVENA* L. Wild Crop Relatives: Genomic & Breeding Resources. Cereals. Editor: Chittaranjan Kole. Springer – Heidelberg, Berlin, New York, Tokyo. 2011. 109-184 p.
- *Avena* webpage http://vir.nw.ru/avena/

Distribution of local ( ) and breeding varieties ( ) of cultivated oat of VIR global collection



Taxonomy of subgenus *Avena* of genus *Avena* L.

Section	Species			Genome	2n
	wild		cultivated		
	floret disarticulated	spikelet diarticulated			
Aristulatae	A. clauda Dur.	A. pilosa M.B.		Cp	14
(Malz.)	A. longiglumis Dur.			Al	
Losk. comb. nova	A. damascena Rajh.et Baum			Ad	
	A .prostrata Ladiz.			Ap	
	A. wiestii Steud.	A. atlantica Baum		As	
	A. hirtula Lagas.		A. strigosa Schreb.	As	
	A. barbata Pott.			AB	28
	A. vaviloviana Mordv.		A. abyssinica Hochst.	AB	
Avena (L.) Losk.		A. ventricosa Balan.		Cv	14
comb. nova		A. bruhnsiana Grun.		Cv	
		A. canariensis Baum		Ac	
		A. agadiriana Baum et Fed.		AB	28
		A. magna Murphy et Terr.		AC	
		A. murphyi Ladiz.		AC	
		A. insularis Ladiz.		AC?	
	A. fatua L.	A. sterilis L.	A. byzantina C.Koch	ACD	42
	A. occidentalis Dur.	A. ludoviciana Dur.	A. sativa L.	ACD	

Intra-specific taxonomy of cultivated species of VIR oat collection

№	Species	Subspecies	Number of botanical varieties
	Diploid species (2n=14)		
1.	A. strigosa Schreb.	strigosa	9
		brevis	8
		nudibrevis	1
	Tetraploid species (2n=28)		
2.	A. abyssinica Hochst.		5
	Hexaploid species (2n=42)		
3.	A. sativa L.	sativa	27
		nudisativa	7
4.	A. byzantina C.Koch	byzantina	13
		nodipubescens	3
		denudata	1
	Total		74

A. sativa subsp. *nudisativa*

A. strigosa subsp. *nudibrevis*

Naked subspecies of *Avena sativa* L. and *Avena strigosa* Schreb.

"*A special group of thin-husked and naked oats worthy of interest from both botanical and practical points of view have been found in northwestern Mongolia.*

It has been established that all agricultural regions of Mongolia show links with the mountainous provinces of Central China.

It means that unknown diversity of naked oats is concentrated in China".

1887 - 2012

N.I.Vavilov, 1923

Botanical varieties of
A. sativa subsp. nudisativa

var. *inermis* Koern.

var. *chinensis* (Fisch. et Roem. et Schult) Doell.

var. *maculate* Mordv. ex Rod. et Sold.

var. *mongolica* (Pissar. ex Vav.) Mordv.

var. *gymnocarpa* Koern.

var. *affinis* Koern.

var. *sibirica* Ganichev

Investigation of phylogenetic relationships and evaluation of peculiarities of evolutionary processes in Avena species using morphological, botanical, biochemical, chromosomal and molecular markers, 2007-2010

The diploid oat species containing the Cp genome— *Avena pilosa* and *A. clauda* —were studied using C-banding, fluorescence *in situ* hybridization with probes pTa71 and pTa794, and electrophoresis of grain storage proteins (avenins).

Species with the C genome differed considerably from the species of the A genome group in the karyotype structure, heterochromatin type and distribution, relative positions of the 45S and 5S rRNA gene loci, and avenin patterns.

These facts confirmed that the C genome had diverged from the ancestral genome before the radiation of the various A genome.

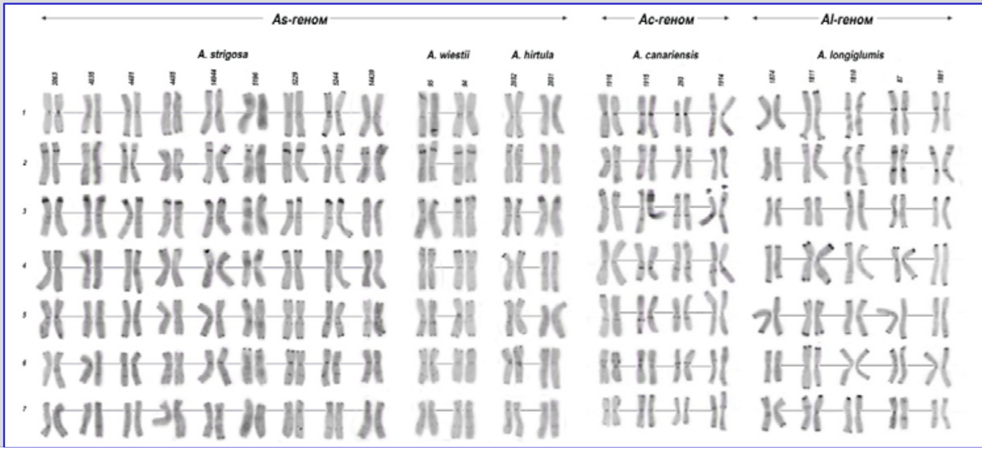
Presumably, further evolution of the A- and C-genome species occurred separately.

Shelukhina O. Yu., Badaeva E. D., Brezhneva T. A., Loskutov I. G., Pukhalsky V. A.
Comparative Analysis of Diploid Species of *Avena* L. Using Cytogenetic and Biochemical Markers: *Avena pilosa* M. B. and *A. claudа* Dur.
Russian Journal of Genetics, 2008, Vol. 44, No. 9, p. 1087–1091.

The diploid oat species containing the A genome of two types (Al and Ac) were studied by electrophoresis of grain storage proteins (avenins), chromosome C-banding, *and in situ* hybridization with probes pTa71 and pTa794.

The karyotypes of the studied species displayed similar C-banding patterns but differed in size and morphology of several chromosomes, presumably, resulting from structural rearrangements that took place during the divergence of A genomes from a common ancestor. *In situ* hybridization demonstrated an identical location of the 45S and 5S rRNA gene loci in *Avena canariensis* and *A. longiglumis* similar to that in the *A. strigosa* genome.

However, the 5S rDNA locus in *A. longiglumis* (*5S rDNA1*) was considerably decreased in the chromosome 3Al long arm. The analysis demonstrated that these oat species were similar in the avenin component composition, although individual accessions differed in the electrophoretic mobilities of certain components. A considerable similarity of *A. canariensis* and *A. longiglumis* to the *Avena* diploid species carrying the As genome variant was demonstrated.

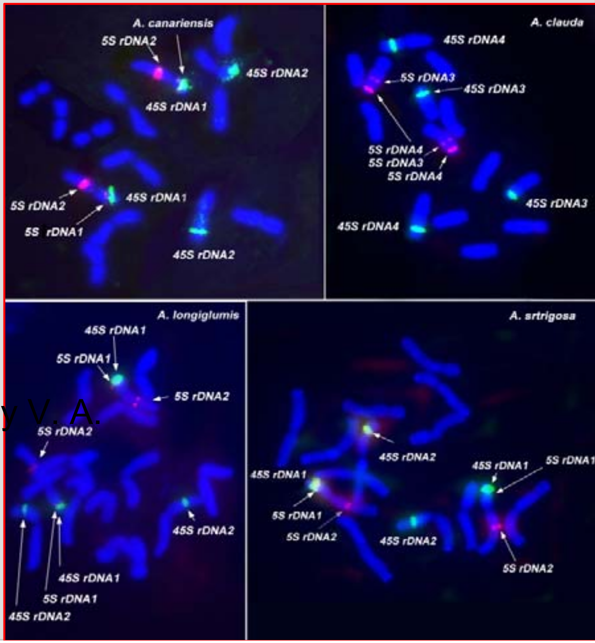


Shelukhina O. Yu., Badaeva E. D., Brezhneva T. A., Loskutov I. G., Pukhalsky V. A.
Comparative Analysis of Diploid Species of *Avena* L. Using Cytogenetic and Biochemical Markers: *Avena canariensis* Baum et Fedak and *A. longiglumis* Dur.
Russian Journal of Genetics, 2008, Vol. 44, No. 6, pp. 694–701.

Tetraploid oat species *Avena abyssinica, A. vaviloviana, A. barbata*, and *A. agadiriana* were studied using C-banding technique, *in situ* hybridization with the 45S and 5S rDNA probes, and RAPD analysis in comparison with the diploid species carrying different types of the A-genome (*A. wiestii*, As; *A. longiglumis*, Al; *A. canariensis*, Ac; *A. damascena*, Ad, *A. prostrata*, Ap).

The investigation confirmed that all four tetraploids belong to the same AB-genome group; however *A. agadiriana* occupies distinct position among others. The C-banding, FISH, and RAPD analyses showed that *A. abyssinica, A. vaviloviana*, and *A. barbata* are very similar; most probably they originated from a common tetraploid ancestor as a result of minor translocations and alterations of C-banding polymorphism system.

AB-genome species are closely related with the A-genome diploids, and an As-genome species may be regarded as the most probable donor of their A-genome. Although their second diploid progenitor has not been identified, it seems unlikely that it belongs to the As-genome group. The exact diploid progenitors of *A. agadiriana* have not been determined; however our results suggest that at least one of them could be related to *A. damascena*.



Badaeva E. D., Shelukhina O. Yu., Goryunova S. V., Loskutov I. G., Pukhalskiy V. A.
Phylogenetic Relationships of Tetraploid AB-Genome
Avena Species Evaluated by Means of Cytogenetic (C-Banding and FISH) and RAPD Analyses.
Journal of Botany. Volume 2010, Article ID 742307, 13 pages
doi:10.1155/2010/742307

The chromosome set of *Avena macrostachya* Balansa ex Coss. et Durieu was analyzed using C-banding and fluorescence *in situ* hybridization with 5S and 18S-5.8S-26S rRNA gene probes, and the results were compared with the C-genome diploid *Avena* L. species.

The location of major nucleolar organizer regions and 5S rDNA sites on different chromosomes confirmed the affiliation of *A. macrostachya* with the C-genome group. However, the symmetric karyotype, the absence of ‘‘diffuse heterochromatin’’, and the location of large C-band complexes in proximal chromosome regions pointed to an isolated position of *A. macrostachya* from other *Avena* species. Based on the distribution of rDNA loci on

the C-genome chromosomes of diploid and polyploid *Avena* species, we propose a model of the chromosome alterations

that occurred during the evolution of oat species.

Badaeva E. D., Shelukhina O. Yu, Diederichsen A., Loskutov I.G., Pukhalskiy V. A Comparative cytogenetic analysis of *Avena macrostachya* and diploid C-genome *Avena* species. Genome, 53, 2010, 1-13.

C-banding of chromosomes and *in situ* hybridization with the probes pTa71 and pTa794 were used for a comparative cytogenetic study of the three tetraploid oat species with the A and C genomes: *Avena insularis, A. magna,* and *A. murphyi.* These species were similar in the structure and C-banding patterns of several chromosomes as well as in the location of the loci 5S rRNA genes and major NOR sites; however, they differed in the number and localization of minor 45S rDNA loci as well as in the morphology and distribution of heterochromatin in some chromosomes. According to the data obtained, *A. insularis* is closer to *A. magna* , whereas *A. murphyi* is somewhat separated from these two species.

Presumably, all the three studied species originated from the same tetraploid ancestor, and their divergence is connected with various species-specific chromosome rearrangements.

The evolution of *A. murphyi* is likely to have occurred independently of the other two species.

Shelukhina O. Yu., Badaeva E. D., Loskutov I. G., Pukhal'sky V. A.
A Comparative Cytogenetic Study of the Tetraploid Oat Species
with the A and C Genomes: *Avena insularis, A. magna* , and *A. murphyi*.
Russian Journal of Genetics, 2007, Vol. 43, No. 6, pp. 613–626.

Pathway of evolution of Avena species*

*Loskutov I.G., Rines H.W. *AVENA* L. Wild Crop Relatives:
Genomic & Breeding Resources. Editor: Chittaranjan Kole.
Springer – Heidelberg, Berlin, New York, Tokyo. 2011. 109-184 p.

List of reference-catalogues of evaluation of VIR oat collection, 1984-2010

№	Characters	Number of catalogues	Number of evaluated accessions
1.	Agronomics traits under different conditions	9	7 972
2.	Disease and pest resistance	3	7 776
3.	Biochemical composition	3	6 260
4.	Photoperiod insensitive	3	559
	Total:	**18**	**22 567**

The VIR's oat donors of semi-dwarfness, developed in 2000-2011

VIR number	Donor name	Pedigree	Gene	Plant height, CM	Lodging resistance, score
14725	BORSI	Borrus × C.I. 8447	Dw-7	85,0±6,7	7
14827	OMIHO	Omihi × Ohau	Probably Dw-6	79,7±9,4	9
14858	BOROT	Borrus × OT 207	Dw-6	84,7±9,5	7
14862	SOKU	Sovetsky × к-14176	Dw-6	**65,0±8,3**	9
14961	HANOMI	к-14324 × Omihi	Probably Dw-6	86,1±8,3	7
15066	SOVOT	Sovetsky × OT 207	Dw-6	88,3±8,7	5
15118	HANOMI 2	к-14324 × Omihi	Probably Dw-6	86,5±8,5	7
15175	RAPEN	к-14333 × Pennline 6571	Dw-6	85,0±9,0	9
15230	BORRAV	Borrus × Av 21/1	Dw-8	**53,0±5,4**	9
пр-4526	BORRAV 2	Borrus × Av 21/1	Dw-8	**50,0±5,3**	9
Standart	**BORRUS**			**98,5 ±2,8**	**5**

Daylength insensitive accessions of oat, 2008-2011

VIR catalogue number	Name of accessions	Origin	Cphot
15111	L 15	Columbia	1,27
14994	Yung 492	China	1,12
14854	CAV 2700	Turkey	1,21
15039	Local	Syria	1,21
15173	Mitika	Australia	1,21
13900	Pennline 6571	USA	1,26
12233	Chihuahua	Mexico	1,23
12358	Paramo	Mexico	1,26
13243	Soroca	Columbia	1,21
14730	Pluton-INIA	Chili	1,23
14541	Yilgarn	Australia	1,18
14841	Pallinup	Australia	1,17

Crown rust - *Puccinia coronata* Cda.
f. sp. *avenae* Faser et Led.,

Stem rust - *Puccinia graminis* Pers.
f. sp. *avenae* Eriks.

A. hirtula Lag.

Resistance to mildew - Eg-04

A. barbata Pott.

Resistance to crown rust - Pc-69
Resistance to mildew - Eg-04

A. magna Murph. et Terr.

Resistance to crown rust - Pc-91, Pc-96

A. sterilis L.

Resistance to crown rust -
Pc-02, Pc-36, Pc-38-39, Pc-40-43, Pc-45-50, Pc-54-59, Pc-60-65, Pc-66-69
Resistance to stem rus - Pg-13, Pg-15

Perennial crosspolinated autotetraploid – *A. macrostachya* Balan. - endemic species of Atlas mountains (Algeria) – has resistance practical to all oat diseases

A. occidentalis Dur. – endemic species of Canary islands (Spain) - Some accessions have high resistance to crown rust, Helminthosporium and tolerance to BYDV.

The sources of oat for resistance to BYDV (VIR-VNIIF)

VIR catalogue	Name of accessions	Origin
11222	Artemovsky 107	Ukraine
13576	Maris Alf	Great Britain
12325	FF 64-74	Canada
14316	IL 86-1158	USA
14319	IL 86-5698	USA
14320	IL 86-6404	USA
14731	IL 86-5262	USA
14732	IL 85-1538	USA
14837	Blaze	USA
14900	IL 2901	USA

The sources of oat for resistance to Helminthosporium (VIR-VIZR)

VIR catalogue	Name of accessions	Origin
13952	Krasnoobsky	Russia
13846	Chernigovsky 27	Ukraine
13579	Orlando	Great Britain
14239	Zlatak	Czech
12101	PC 47*	Canada
12172	Rodney M*	Canada
14219	PC 50-4*	Canada
14397	PC 67*	Canada
14316	IL 86-1158*	USA

*Resistant to other diseases

Infections of grains of covered and naked oat by FHB (VIR-VIZR, 2008-09 г.)

Subspecies		Infections of grains, %	
		average	divers
Naked oat		1.9	0 - 6
Covered oat	in glumes	17.3	0 - 100
	cariopsis	9.6	0 - 98

Diversity of oat accessions for resistance to Fusarium Head Blight, VIR-VIZR, 2008-2010

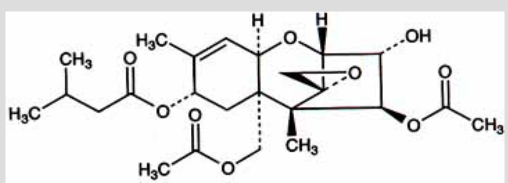
VIR catalogue	Name of accessions	Origin	FHB, %
1926	Local*	China	0
1928	Local*	China	0
2471	Local*	Mongolia	0
15014	Levsha*	Russia, Kemerovo	0
14851	Numbat*	Австралия	0
14960	Vyatsky*	Russia, Kirov	2
14231	Ulov	Russia, Moscow	6
13780	Skakun	Russia, Moscow	46
14597	Sprint 2	Russia, Krasnoufimsk	6
15013	Argument	Russia, Altai	6
14648	Argamak	Russia, Kirov	0
11840	Borrus	Germany	18

***Naked cultivars**

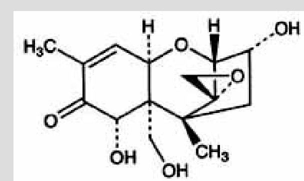
Mycotoxin contents in the hulled and hull-less oats

No. of oats samples	T-2 toxin, ppb		DON, ppb	
	Mean	Range	Mean	Range
hull-less (n=28)	178	0 - 774	346	57 - 1256
hulled (n=181)	543	0 - 5620	728	53 - 11190

F. sporotrichioides, F. langsethiae



F. graminearum, F. culmorum



The sources of disease resistance in *Avena* genera*

Species	Genome	PC	PG	EG	Septoria	BYDV	Hilmintosp.
A. ventricosa	Cv	+	+	+	+		
A. pilosa	Cp	+	+	+	+		
A. prostrata	Ap	+	+	+	+		
A. damascena	Ad	+	+	+	+	+	
A. longiglumis	Al	+	+	+	+	+	+
A. canariensis	Ac	+	+		+		
A. wiestii	As	+		+	+		+
A. hirtula	As	+	+	+	+	+	+
A. atlantica	As			+	+		+
A. strigosa	As	+	+	+	+	+	+
A. barbata	AB	+	+	+	+	+	+
A. vaviloviana	AB	+	+		+	+	
A. abyssinica	AB	+	+		+		+
A. magna	AC	+	+			+	+
A. macrostachya	CC?	+	+	+	+	+	+
A. fatua	ACD	+	+	+	+	+	+
A. occidentalis	ACD	+	+	+		+	+
A. ludoviciana	ACD	+	+	+	+	+	+
A. sterilis	ACD	+	+	+	+	+	+
A. sativa	ACD	+	+	+	+	+	+

*Loskutov I.G., Rines H.W. *AVENA* L. Wild Crop Relatives: Genomic & Breeding Resources. Editor: Chittaranjan Kole. Springer – Heidelberg, Berlin, New York, Tokyo. 2011. 109-184 p.

Oat varieties with high oil content, 2009-2011

VIR catalogue	Name of accession	Origin	Oil content, %
14960	Vaytsky*	Russia, Kirov	8,1
14648	Argamak	Russia, Kirov	6,9
15014	Levsha*	Russia, Kemerovo	6,8
15180	Piruet	Russia, Ul'aynovsk	6,8
15116	Murom*	Russia, Kemerovo	8,7
15117	Pomor*	Russia, Kemerovo	9,0
15183	Taidon*	Russia, Kemerovo	9,8
15132	PI 401772	France	9,5
15160	MF 9521-79*	USA	9,0
15126	Matilda	Sweden	9,4
11840	Borrus	Germany	6,3

*Naked cultivars

Fatty acid composition of oat varieties

VIR catalogue	Name of accessoin	Origin	Fatty acids					
			16:0	18:0	18:1	18:2	18:3	20:1
14960	Vaytsky*	Russia, Kirov	21,4	4,3	41,0	28,3	4,5	0,0
14648	Argamak	Russia, Kirov	21,2	1,6	40,7	32,9	1,4	0,2
14957	Gunter	Russia, Kirov	19,3	1,1	42,6	32,4	1,5	0,6
13918	Kirovetz	Russia, Kirov	17,8	1,3	42,8	34,0	1,6	0,5
14857	Krechet	Russia, Kirov	20,1	2,0	39,6	33,5	1,7	0,5
14943	Local	Great Britain	19,4	1,8	45,4	29,3	6,6	3,1
14781	Faust	Russia, Kirov	22,1	1,6	41,5	30,3	1,3	0,4
15177	Derbi	Russia, Ul'aynovsk	21,1	2,3	36,4	35,0	1,6	0,6
15180	Piruet	Russia, Ul'aynovsk	23,5	1,1	40,3	31,3	1,5	0,2
1931	Hull-less*	China	18,1	1,8	**51,4**	21,8	3,4	2,5
11840	Borrus	Germany	22,3	1,6	35,5	37,2	1,3	0,6

***Naked cultivars**

Diversity of β-glucane content in oat varieties, VIR-NGB and VIR-Protein comp., 2008-2010

VIR catalogue	Name of accession	Origin	β-glucane contant, %
14717	Pushkinsky*	Russia, St-Petersburg	6,8
13780	Skakun	Russia, Moscow	4,7
14787	Privet	Russia, Moscow	5,5
15176	Lev	Russia, Moscow.	4,7
13918	Kirovetz	Russia, Kirov	5,1
14648	Argamak	Russia, Kirov	4,8
14373	Fakir	Russia, Kirov	4,3
15068	Konkur	Russia, Ul'aynovsk	5,9
15117	Pomor*	Russia, Kemerovo	6,7
11840	Borrus	Germany	5,8

***Naked cultivars**

Diversity of sterols and tocopherols content in oat varieties, VIR-VNIIZh, 2008-2009

VIR catalogue	Name of accession	Origin	Content	
			sterols, %	tocopherols, мg%
14648	Argamak	Russia, Kirov	0,570	219
13780	Skakun	Russia, Moscow	0,642	180
13918	Kirovetz	Russia, Kirov	0,723	227
13957	Gunter	Russia, Kirov	0,670	236
14373	Fakir	Russia, Kirov	0,810	235
14781	Faust	Russia, Kirov	0,770	195
15180	Piruet	Russia, Ul'aynovsk	0,638	167
5184	Local	Spain	1,179	283
6963	Local	Japan	0,955	169
2472	Local*	Mongolia	0,969	415
11840	Borrus	Germany	0,998	219

*Naked cultivars

Dietary characters of oat, VIR-Protein comp., 2008-2011

A gluten-free diet for celiac patients is based on functional food which prevent pathological changes in people genetically predisposed to this diseases.

An evaluation of several accessions of oat has shown that one husked cultivar Argamak (Russia) and two naked cultivars Pushkisky (Russia) and Rheanon (UK) only manifested an unusual reaction.

The sources of high biochemical components content in oat kernel*

Species	Genome	Protein	Oil	Starch	β glucane	Tocopherol/ Sterols
A. bruhnsiana	Cv	+				
A. ventricosa	Cv	+	+			
A. pilosa	Cp	+	+			
A. prostrata	Ap	+				
A. damascena	Ad					
A. longiglumis	Al	+	+			
A. canariensis	Ac	+	+			
A. wiestii	As	+	+			
A. hirtula	As	+	+			
A. atlantica	As	+				
A. strigosa	As	+			+	
A. barbata	AB	+	+			
A. vaviloviana	AB	+	+		+	
A. abyssinica	AB		+	+		
A. magna	AC	+	+			
A. fatua	ACD	+	+	+	+	
A. occidentalis	ACD	+	+		+	
A. ludoviciana	ACD	+	+	+	+	
A. sterilis	ACD	+	+	+	+	
A. sativa	ACD	+	+	+	+	+

*Loskutov I.G., Rines H.W. *AVENA* L. Wild Crop Relatives: Genomic & Breeding Resources. Editor: Chittaranjan Kole. Springer – Heidelberg, Berlin, New York, Tokyo. 2011. 109-184 p.

Oat Breeding Centers in Russian Federation

Министерство сельского хозяйства Российской Федерации
Федеральное государственное бюджетное учреждение
«Государственная комиссия Российской Федерации
по испытанию и охране селекционных достижений»

АВТОРСКОЕ СВИДЕТЕЛЬСТВО

№ 51775

Овес яровой

ТАЙДОН

выдано в соответствии с решением Государственной комиссии Росси
Федерации по испытанию и охране селекционных достижений от 06.04.2

ПО ЗАЯВКЕ № 9154971 С ДАТОЙ ПРИОРИТЕТА 15.12.200

Патентообладатель(и)

Министерство сельского хозяйства Российской Федерации
Федеральное государственное учреждение
«Государственная комиссия Российской Федерации
по испытанию и охране селекционных достижений»

АВТОРСКОЕ СВИДЕТЕЛЬСТВО

№ 46634

Овес яровой

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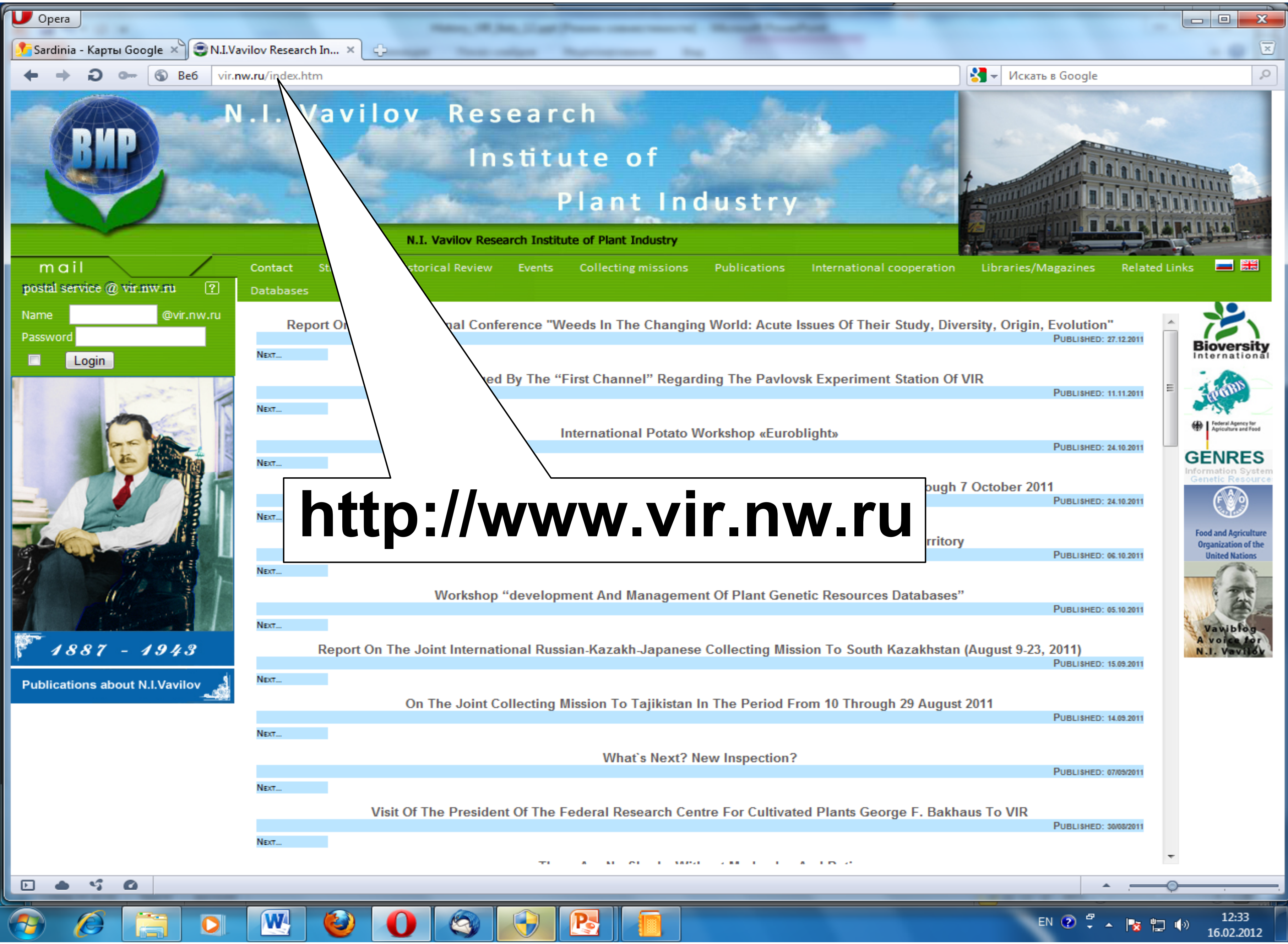
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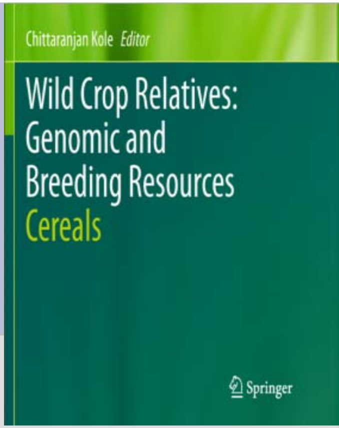

Chapter 3
Avena
Devoted to Ken Frey – oat breeder

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