Structure of the oat genepool at Plant Gene Resources of Canada

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Plant Gene Resources of Canada

(AOWC Ottawa 2014)

Plant Gene Resources of Canada (PGRC) – Ressources Phytogénétiques du Canada

- PGRC was established in 1970 in Ottawa and moved in 1998 to Saskatoon
- The mandate is to acquire, preserve and evaluate the genetic diversity of crops and their wild relatives
- Focus is on germplasm of economic importance or potential for Canada
- Main deliverables of PGRC:
  - Efficient *ex situ* conservation
  - Viable, diverse germplasm to clients
  - Relevant information

Do we need genebanks?

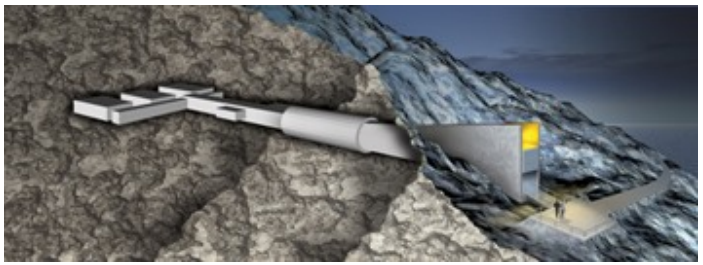
1. *In situ*/on farm

Dynamic, adapting
Evolution
Interaction
For farmers/consumers
Stable?

2. Traditional, active genebanks

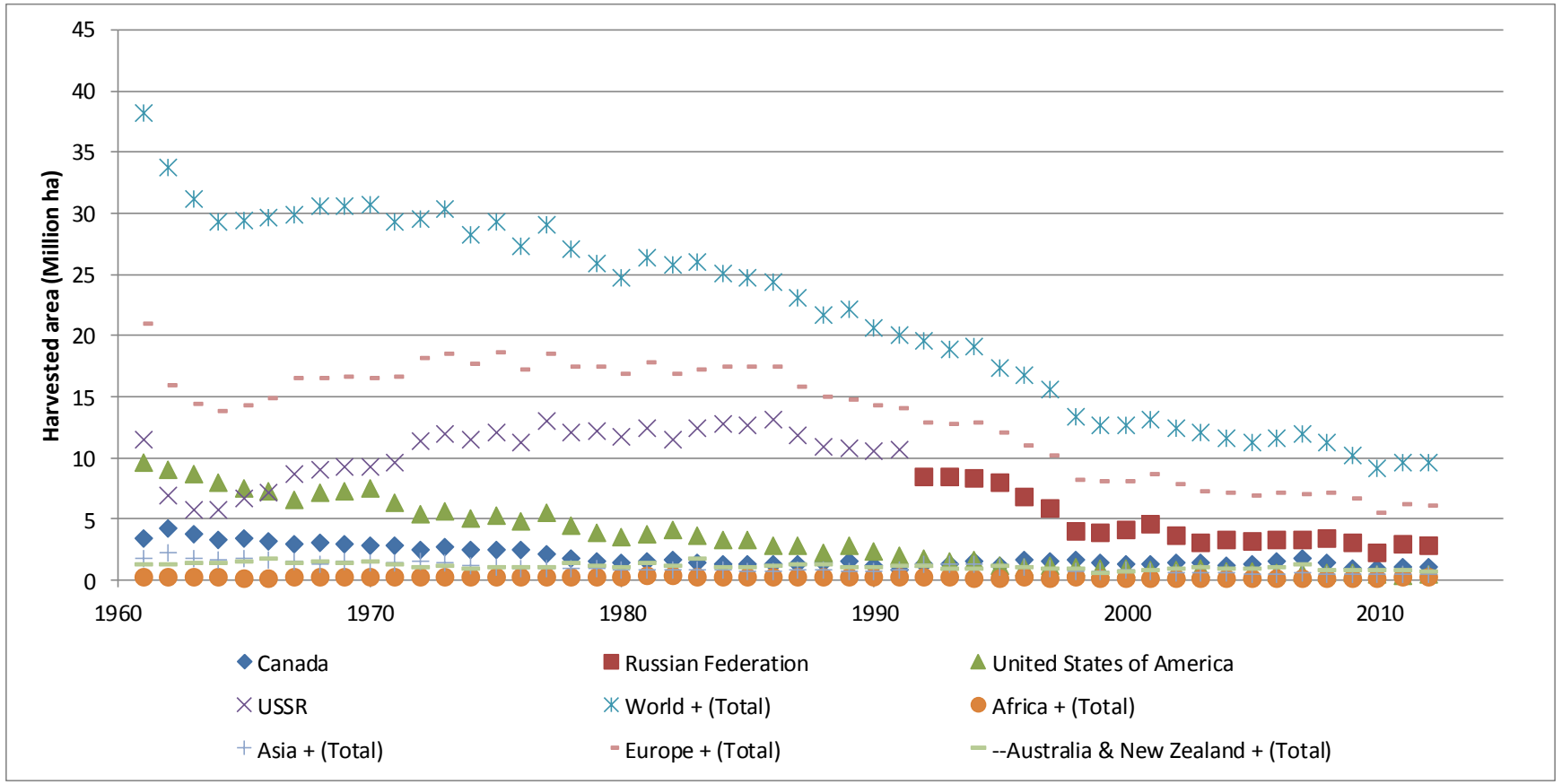
Static?
Storage, assessment
Knowledge
For breeders/research
Stable?

3. Svalbard Global Seed Vault



Very static?
Storage
Administration
For genebank managers
Stable?

Trend in oat production (FAO 2014)



- In the late 18th and early 20th century oat occupied in many northern countries more land than any other cereal
- Since 1945/49 there has been a reduction by 80%
- Lesser decline in Nordic countries and Canada
- Oat breeding programs are ceasing in Europe and North America

What is special about oat?

- None of the International Agricultural Research Centres (CGIAR Consortium) has oat as mandate crop.
- Oat as a crop is most relevant in temperate climates of the north.
- Natural wild oat genepools and oat cultivation areas are geographically disconnected.

Seed storage at PGRC

Working collection:
+ 4ºC, 10-20%RH,
in paper envelopes

Long-term storage:
-18ºC, no air humidity control,
dry seeds in sealed envelopes

What is special about the PGRC Oat collection?

- Collecting of oat genetic resources in the 1960s and 1970s resulted in 7,411 accessions of *Avena* (27% of collection), with emphasis on wild *Avena* species and landraces of *A. sativa*
- World base collection of *Avena* (IBPGR, 1979)
- Broad coverage of the genus *Avena*
- Recent characterization and evaluation of most of the collection
- Extensive evaluation data on rust resistance
- Evaluations on seed oil content and fatty acid patterns
- All data available on Internet (GRIN-CA)
- The utilization of *Avena* crop wild relatives from PGRC germplasm in plant breeding has been very intense

Collaboration essential to bring the potential in genetic resources to reality

(Think "*Fußball*")

- The utilization of *Avena* crop wild relatives from PGRC germplasm in plant breeding has been very intense and successful in Canada
  - Collaboration within AAFC among:
    Botanists/taxonomists (B. Baum)
    Cytologists (T. Rajhathy, H. Thomas, G. Fedak)
    Genebank curators/managers (R. Loiselle, B. Fraleigh, K. Richards)
    Plant Pathologists (J. Chong, B. Menzies, T. Fetch, R. Kutcher)
    Plant Breeders (F.J. Zillinsky, S. Kibite, V. Burrows, J. Mitchell-Fetch)
  - Renewed efforts including molecular approaches (Y.-B. Fu, N. Tinker)
    ....
- Other national and international cooperation (E. Kjellkvist, M. Legget, G. Ladizinsky, I. Loskutov, B. Rossnagel, …)

- Organisations and genebanks (IBPGR/IPGRI/Bioversity International; Global Crop Diversity Trust; VIR, USDA, IPK, NCPGRU, UFRGS, …)

Collecting missions for *Avena* involving Canadian researchers prior to 1972 (Baum et al., 1972)

FIG. 1. Outline of the Mediterranean and Near East areas with the collecting routes undertaken in the three expeditions by the authors.

Avena from collecting missions at PGRC with Canadian participation

Year	Region sampled	Collectors
1964	Mediterranean (Gibraltar, Spain, France, Italy, Greece, Turkey, Libya, Morocco)	Rajhathy, Zilinsky, Harges
1965-1967	Afghanistan	Kuckuck (FAO)
1966	Israel	Fleischman
1970	Turkey, Iran, Afghanistan	Fleischman, Baum, Bennett
1970	Turkey	Kjellquist (FAO)
1970	Iran, Turkey, Iraq, Syria, Lebanon, Algeria, Tunisia, Greece, Israel	Welsh (Rajhathy - Martens: Lebanon - Iraq, Baum: Syria - Turkey; Fleischman - Thomas)
1971	Kenya, Ethiopia	Martens
1971 or 1972	Canary Island	Sampson
1972	Morocco, Tunisia	Martens
before 1974	Ethiopia	
1977	Tbilissi, Georgia, USSR	Martens
1978	Turkey, Iran, Greece	Baum - Fedak - Martens
1980	Spain	Fedak
1982	Turkey, Black Sea	Comeau

Avena L. germplasm at PGRC

Total: 27,808 accessions

Structure by cultivated *vs.* wild

Cultivated taxa 12,502 accessions

Avena brevis Roth	41
Avena hispanica Ard.	16
Avena strigosa Schreb.	162
Avena nuda L.	13
Avena abyssinica Hochst.	254
Avena sativa L.	12016

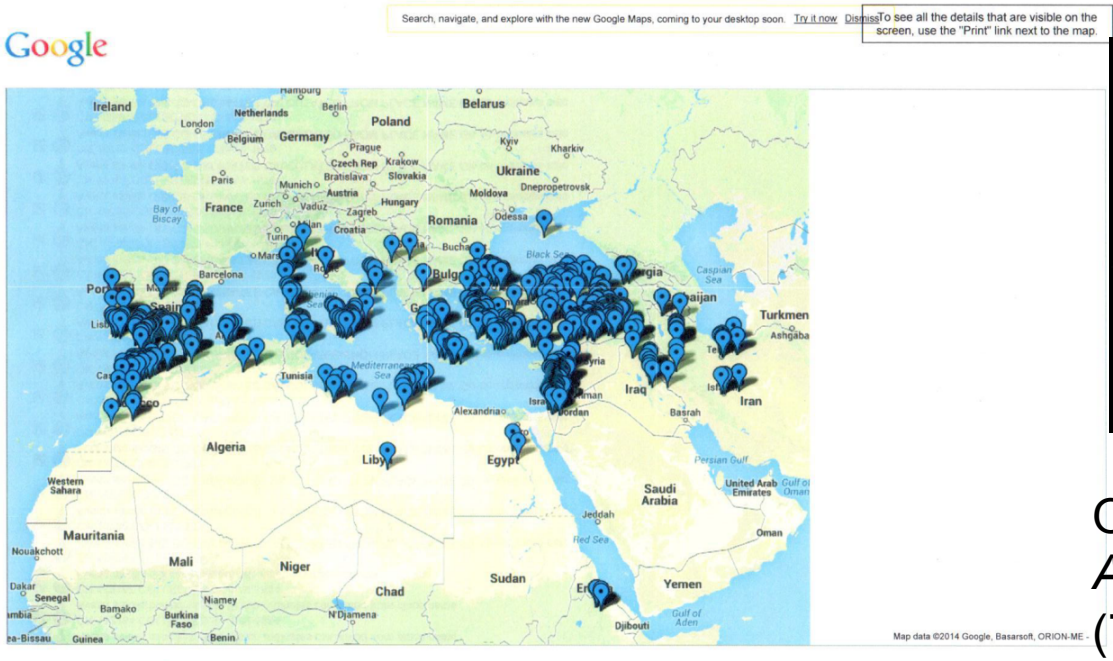
Wild taxa 15,305 accessions

Avena barbata Pott ex Link	2106
Avena sterilis L.	11524
Avena fatua L.	644
20 other *Avena* wild species	1031

Structure by geographic origin

(E. Timmermans, PGRC Database Manager)

http://maps.google.com/maps?q=http://pgrc3.agr.gc.ca/STERILIS_ACCESSION_AVENA.KML



Origin of 11, 304
A. sterilis accessions at PGRC
(7,602 with coordinates)

Displaying content from pgrc3.agr.gc.ca
The content displayed below and overlaid onto this map is provided by a third party, and Google is not responsible for it. Information you enter below may become available to the third party.
Contents

- CN 108755 COLLECTED:10-MAY-1925
  Avena sterilis Elevation derived from the GTOPO30 dataset (0.1 x 0.1 degree grid
- CN 108756 COLLECTED:01-APR-1939
  Avena sterilis Elevation derived from the GTOPO30 dataset (0.1 x 0.1 degree grid
- CN 110783 COLLECTED:
  Avena sterilis
- CN 110889 COLLECTED:01-JUN-1984
  Avena sterilis Gis co-ordinates calculated from place name

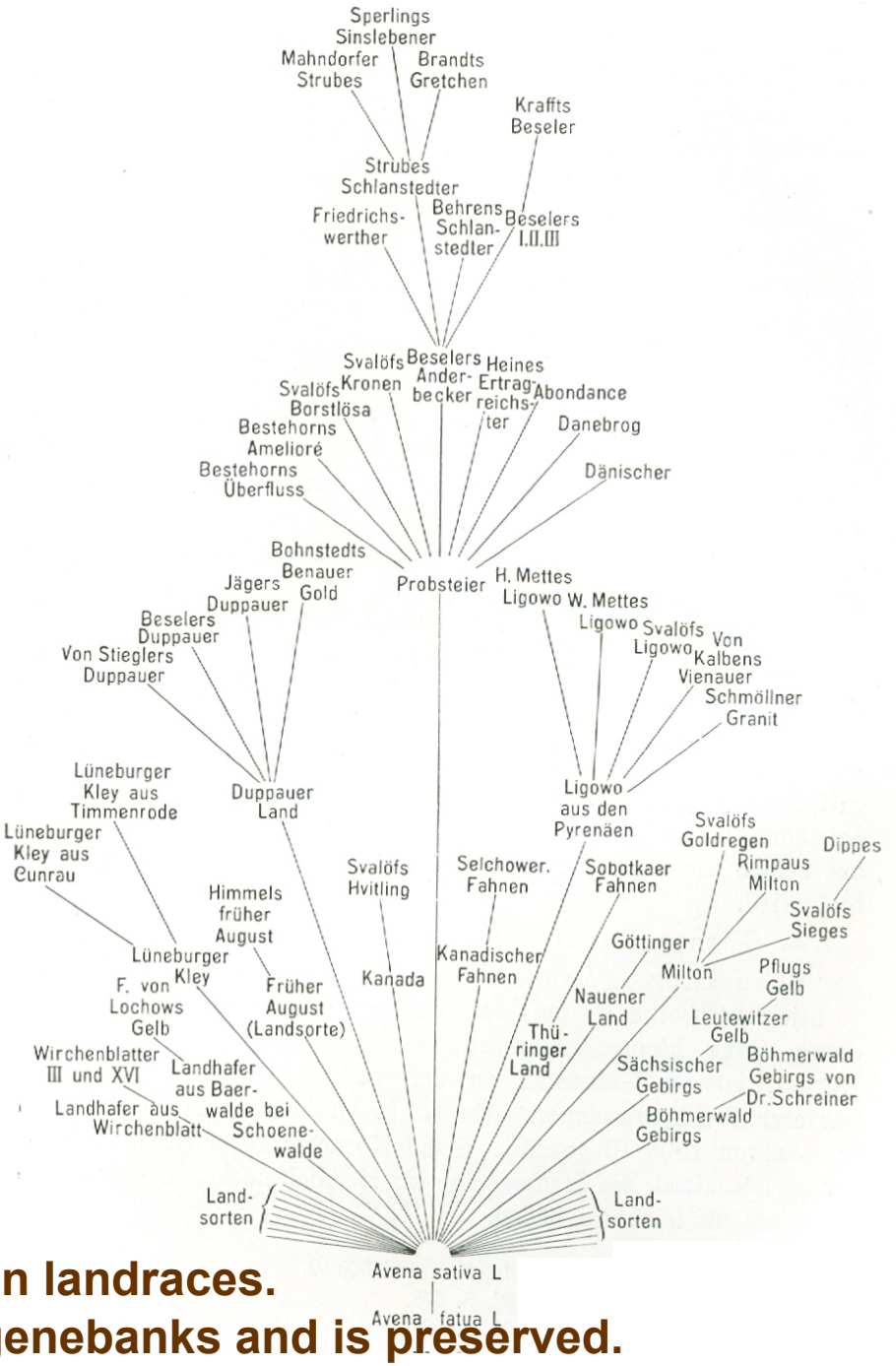
Structure by improvement status

Category	Number accessions
Breeding material and genetic material	5458
Cultivars	3484
Landraces	1338
Uncertain	9
Cultivated material	2072
Wild material	15258

Line selection within oat landraces

Mass selection or line selection within oat landraces resulted in 18 cultivars from one landrace (Probsteier). (Zade 1918)

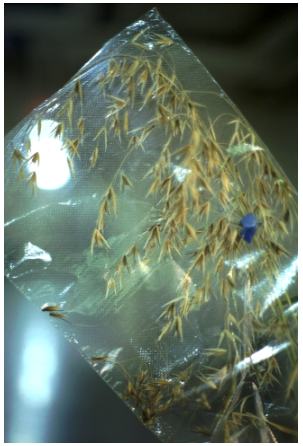
In Swedish landraces selected:
136 biotypes in Smålandshavre
137 biotrypes in Bohushavre
120 biotypes in Dalslandshavre
(Granhall 1938)



Conclusion:
There was a wide range of diversity within landraces.
Only a fraction of this diversity entered genebanks and is preserved.

Structure by regeneration status

	***A. sativa* sensu stricto: Cultivated, hexaploid oat**		**Other *Avena* species**	
Site	Greenhouse	Field	Greenhouse	Field
Planted 1998-2013	823	16,054	2,440	5,078
Sub-total	16,877		7,518	
Total	24,395			



About 55 % of wild A*vena* accessions at PGRC needs regeneration.

Structure based on uniqueness of material at PGRC

Duplication between USDA and PGRC

PGRC	USDA	PGRC	USDA	Duplicates PGRC-USDA
total	**total**	**only**	**only**	
27,230	24,447	9,484	7,246	17,561

- 36% of accessions at PGRC are not duplicated in USDA
- Estimate: 10% of PGRC accessions are not duplicated elsewhere

Duplication within the PGRC collection

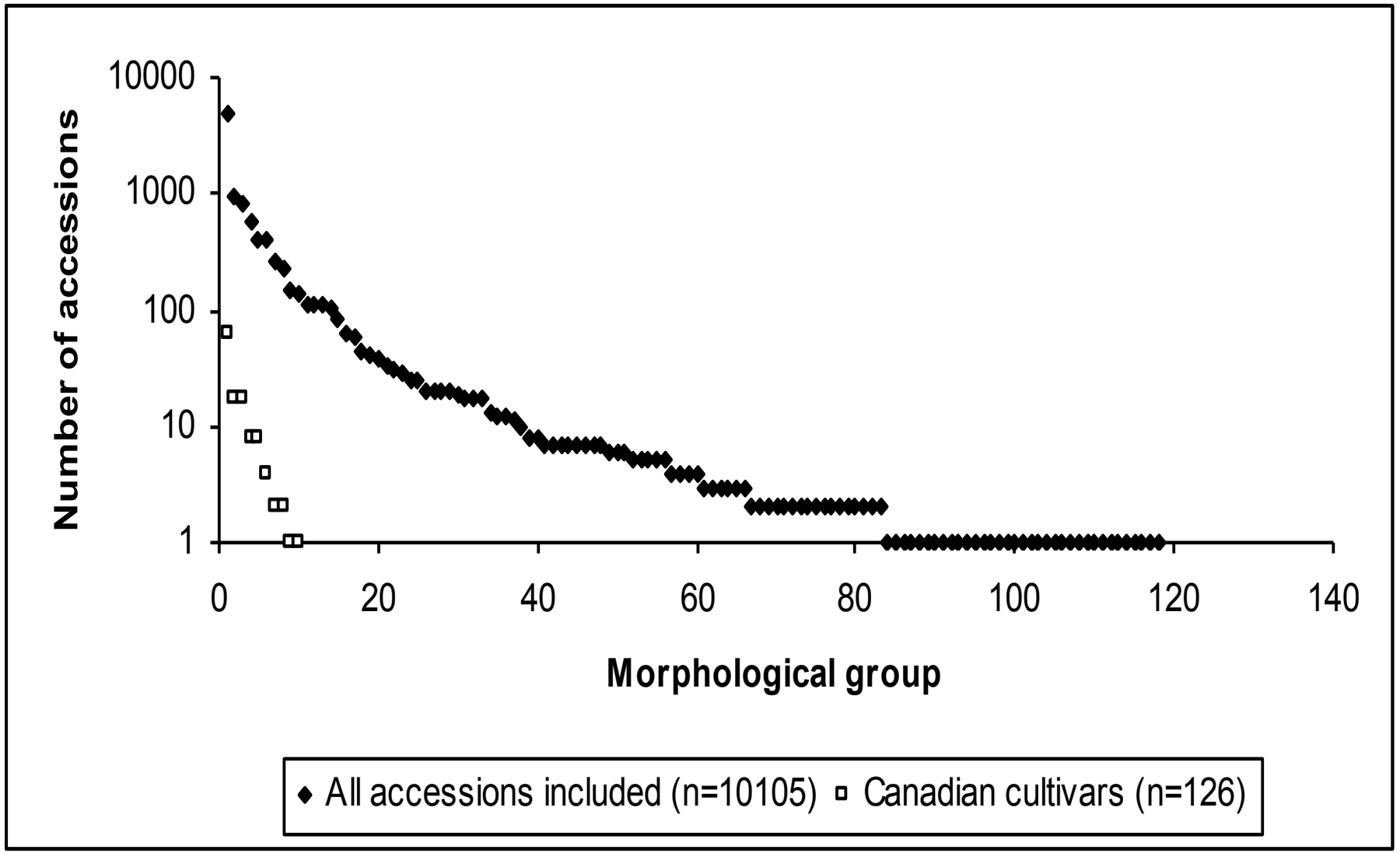
- Example cultivar ‘Silvermine’ (US, 1895) – “the heaviest yielding oat in the world”
- Competition for the best name ($300 in gold award) resulted in many names
- In total 71 accessions at PGRC

Name	Accessions at PGRC
Silvermine	25
Big Four	11
Banner	10
Welcome	6
20th Century	4
American Banner	4
Czar of Russia	4
Alexander	2
College Wonder	2
College Success	1
Minnessota No. 281	1
Schoenen	1
Granary Filler	-
Great American	-
Minnessota No. 368	-
Nameless White Beauty	-
Stiffstraw	-
White Alaska	-

Descriptors in oat

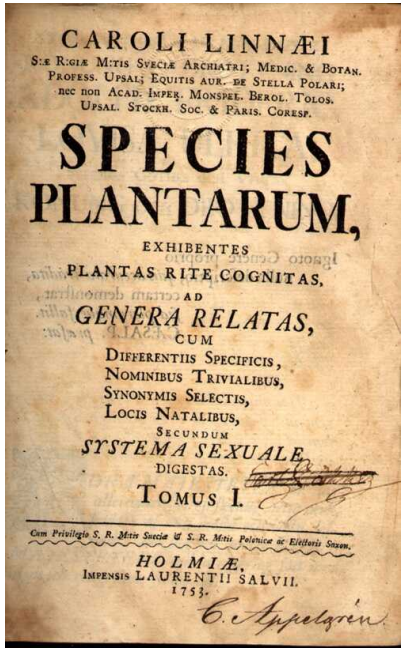
- **Phenological characters: 3**
- **Morphological characters: 34**
  - **Vegetative plant parts: 10**
  - **Generative plant parts: 24**

Concentration of certain phenotypes in the PGRC *A. sativa* collection



Taxonomy as a tool for structuring and communicating diversity

Why is taxonomy not popular in crop science?



CAROLI LINNÆI
S:æ R:giæ M:tis Sveciæ Archiatri; Medic. & Botan. Profess. Upsal; Equitis aur. de Stella Polari; nec non Acad. Imper. Monspel. Berol. Tolos. Upsal. Stockh. Soc. & Paris. Coresp.

SPECIES PLANTARUM,

EXHIBENTES
PLANTAS RITE COGNITAS,
AD
GENERA RELATAS,
CUM
DIFFERENTIIS SPECIFICIS,
NOMINIBUS TRIVIALIBUS,
SYNONYMIS SELECTIS,
LOCIS NATALIBUS,
SECUNDUM
SYSTEMA SEXUALE
DIGESTAS.

TOMUS I.

Cum Privilegio S. R. Mtis Suecia & S. R. Mtis Poloniæ ac Electoris Saxon.

HOLMIÆ,
IMPENSIS LAURENTII SALVII.
1753.

Carolus Linnaeus (1707-1787) *Critica botanica*:

"I distinguish the species of the Almighty Creator which are true from the abnormal variation of the gardener."

"Cultivated plants are not created, therefore they are not species."

"All monstrous flowers and plants derive their origin from normal forms."

"Such monstrosities, variegated, abnormal, multiplied, double, cruciferous, gigantic, wax fat and charm the eye of the beholder with protean variety so long as gardeners perform daily sacrifice to their idol."

Structure by taxonomy

- GRIN taxonomy recognizes 34 *Avena* taxa. Of these, 32 have the rank of a species.
- PGRC preserves germplasm of 29 species of *Avena*.
- For structuring the genepool and communication, PGRC relies on taxonomy. The characterisation of germplasm at PGRC is based on morphology that results in identification of species.

Diploid *Avena* taxa: 16 species or 6 species?

Avena taxon	Ploidy (2n)	Genome
A. clauda Durieu	14	Cp
A. eriantha Durieu (syn.: *A. pilosa* M.B.)	14	Cp
A. ventricosa Bal. ex Coss. incl. *A. bruhnsiana* Grun.	14	Cv
* *A. strigosa* Schreb.	14	As
* *A. brevis* Roth	14	As
* *A. hispanica* Ard. ex Saggi	14	As
* *A. nuda* L.	14	As
A. hirtula Lag. (incl. *A. prostrata* Ladiz. with genome Ap ?)	14	As
A. wiestii Steudel	14	As
A. matritensis Baum	14	As?
A. lusitanica (Tab. Mor.) Baum	14	As
A. atlantica Baum et Fedak	14	As
A. prostrata Ladiz. (At PGRC following Baum incl. in *A. hirtula* Lag.)	14	Ap
A. canariensis Baum, Rajhathy et Sampson	14	Ac
A. damascena Rajhathy et Baum	14	Ad
A. longiglumis Durieu in Duchartre	14	Al

* Cultivated taxa

Tetraploid *Avena* taxa: 8 species or 6 species?

Avena taxon	Ploidy (2n)	Genome
A. macrostachya Bal. ex Coss. et Durieu	28	MM?
A. agadiriana Baum et Fedak	28	AsB?
A. barbata Pott ex Link - USA: incl. *A. hirsuta* Moench. and *A. atheranta* C. Presl (?)	28	AB
* *A. abyssinica* Hochst.	28	AB
A. vaviloviana (Malz.) Mordv.	28	AB
A. insularis Ladiz.	28	AC
A. maroccana Gandog. (syn. *A. magna* Murphy et Terrell)	28	AC
A. murphyi Ladiz.	28	AC

* Cultivated taxa

Hexaploid *Avena* taxa: 8 species or 1 species?

	Avena taxon	Ploidy (2n)	Genome
	A. atheranta C. Presl (syn.: *A. sterilis* L. subsp. *atheranta* (C. Presl) H. Scholz)	42	ACD
	A. sterilis L. subsp. *sterilis* (Baum includes here subsp. *ludoviciana*)	42	ACD
	A. trichophylla C. Koch (Scholz: belongs to *A. sterilis* subsp. *sterilis)*	42	ACD
	A. sterilis L. subsp. *ludoviciana* (Durieu) Gill. et Magne	42	ACD
*	*A. sativa* L. subsp. *sativa* (Baum does not distignuish any subspecies)	42	ACD
*	*A. sativa* L. subsp. *nudisativa* (Husnot.) Rod. et Sold.	42	ACD
*	*A. sativa* L. subsp. *byzantina* (C. Koch) Romero Zarco	42	ACD
	A. fatua L. (incl. *A. fatua* subsp. *aemulans* (Nevski) H. Schollz)	42	ACD
	A. hybrida Peterm. (syn.: *A. fatua* subsp. *septentrionalis* (Malcev) Malcev)	42	ACD
	A. occidentalis Durieu (syn.: *A. fatua* subsp. *meridionalis* Malcev)	42	ACD

* Cultivated taxa

Challenges in oat taxonomy

- Macro-morphological characters are not sufficient to distinguish among species
- Many species distinguished in the wild species
- Important distinctions within the cultivated hexaploid oat are not reflected in taxonomic treatments of the genus

Issues

- **Botanical determination sometimes incorrect**
- **Micromorphological characters problematic**
- **Chromosome counting useful but difficult**
  - ***A. insularis* (n=7) vs. *A. sterilis* (n=21)**
  - ***A. lusitanica* (n=7) vs. *A. barbata* (n=14)**
  - ***A. murhyi* (n=14) vs. *A. sterilis* (n=21**
  - ***A. prostata* (n=7) vs. *A. barbata* (n=14)**
  - ***A. abyssinica* (n=14) vs. *A. sativa* (n=21)**
- **Taxonomical differences among genebanks or in literature (different species concepts)**

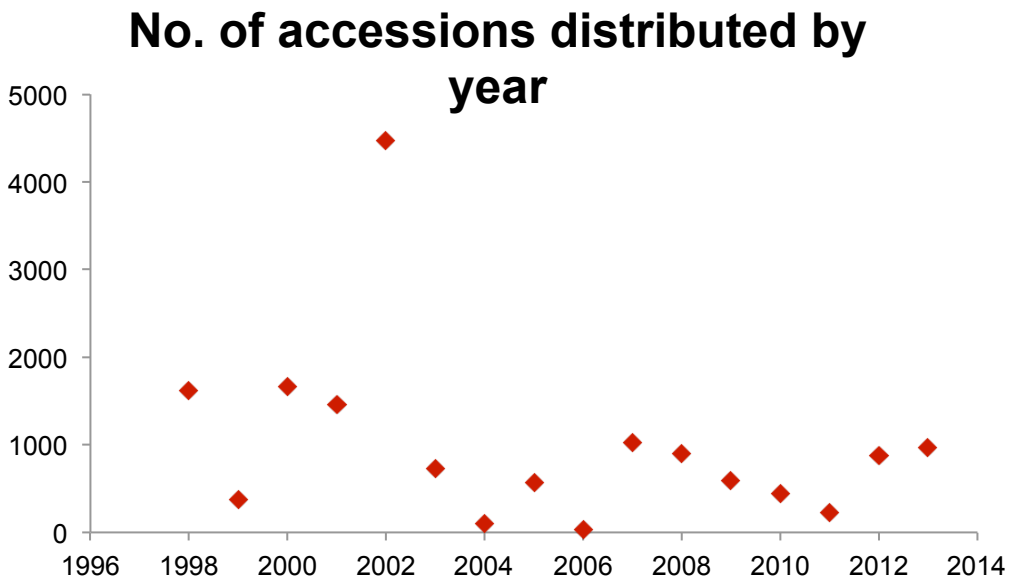
We need structure for orientation.

- The need to recognize differences and structures is essential for orientation within and utilization of the oat genepool.
- Linnean taxonomy arose from this basic need.
- Have molecular genetics rendered morphological and taxonomical concepts obsolete?
- Should taxonomy continue to be the basis for communication?
- Will epigenetics make genetics obsolete?

Avena germplasm in world genebanks (FAO, 2010)

Genebank	Number of Accessions	Proportion of world (%)	Wild species (%)	Landraces (%)	Breeding lines (%)	Cultivars (%)	Other (%)
PGRC, Canada	27,676	21	55	12	20	12	1
USDA	21,195	16	49	14	24	13	
VIR, Russia	11,857	9	19	41	<1	1	39
IPK , Germany	4,799	4	15	33	9	38	4
KARI, Kenya	4,197	3	<1				100
TAMAWC, Australia	3,674	3			<1	<1	99
ICGR, China	3,357	3					100
World (13 others countries included)	**130,653**	**100**	**24**	**14**	**13**	**12**	**37**

Avena distributions by PGRC



- Total 1998-2013: 16,061 accessions
- Per year average: 1000 accessions
- Species: *A. sativa* 33%, *A. sterilis* 31%, *A. barbata* 18% other taxa 18%
- Countries served: Canada 59 % of accessions, 41% to 28 other countries
- Canada is party to the International Treaty on Plant Genetic Resources for Food and Agriculture
- The Standard Material Transfer Agreement of the Treaty is used
- All PGRC oat germplasm is part of the Multilateral System

Scylla and Charybdis dilemma of genebanks (1)

- Preserve and study what is at risk of being lost and challenging to maintain
  - Consequence: There is little or no immediate economic impact

or

- Preserve and study what is presently economically relevant
  - Consequence: Genetic erosion in many neglected and underutilized crops

Scylla and Charybdis dilemma of genebanks (2)

- Maximise overall diversity preserved (many samples, many landrace populations)
  - Consequence: Precision of characterisation of material decreases

or

- Maximise purity and information about preserved material for users that produces replicable results (pure-lined material)
  - Consequence: Diversity may be lost

A challenge in germplasm characterization and preservation: heterogeneous accessions

CN 63882 (PI 190327)
'Scotland Club', dwarf

CN 106550 (VIR-11263)
Landrace from Bulgaria

Strategic decisions required for PGRC

- Which *Avena* diversity needs *ex situ* conservation?
- Should PGRC fill gaps in the Canadian genebank collection from a global perspective?
- How can we improve a globally rational approach to *Avena* conservation?
- In 2007 in St. Petersburg the “Global Oat Diversity Network” was established. Should this initiative be pushed to more activity?

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