GENETIC DIVERSITY, GENE BANKS and THE GLOBAL SVALBARD SEED VAULT

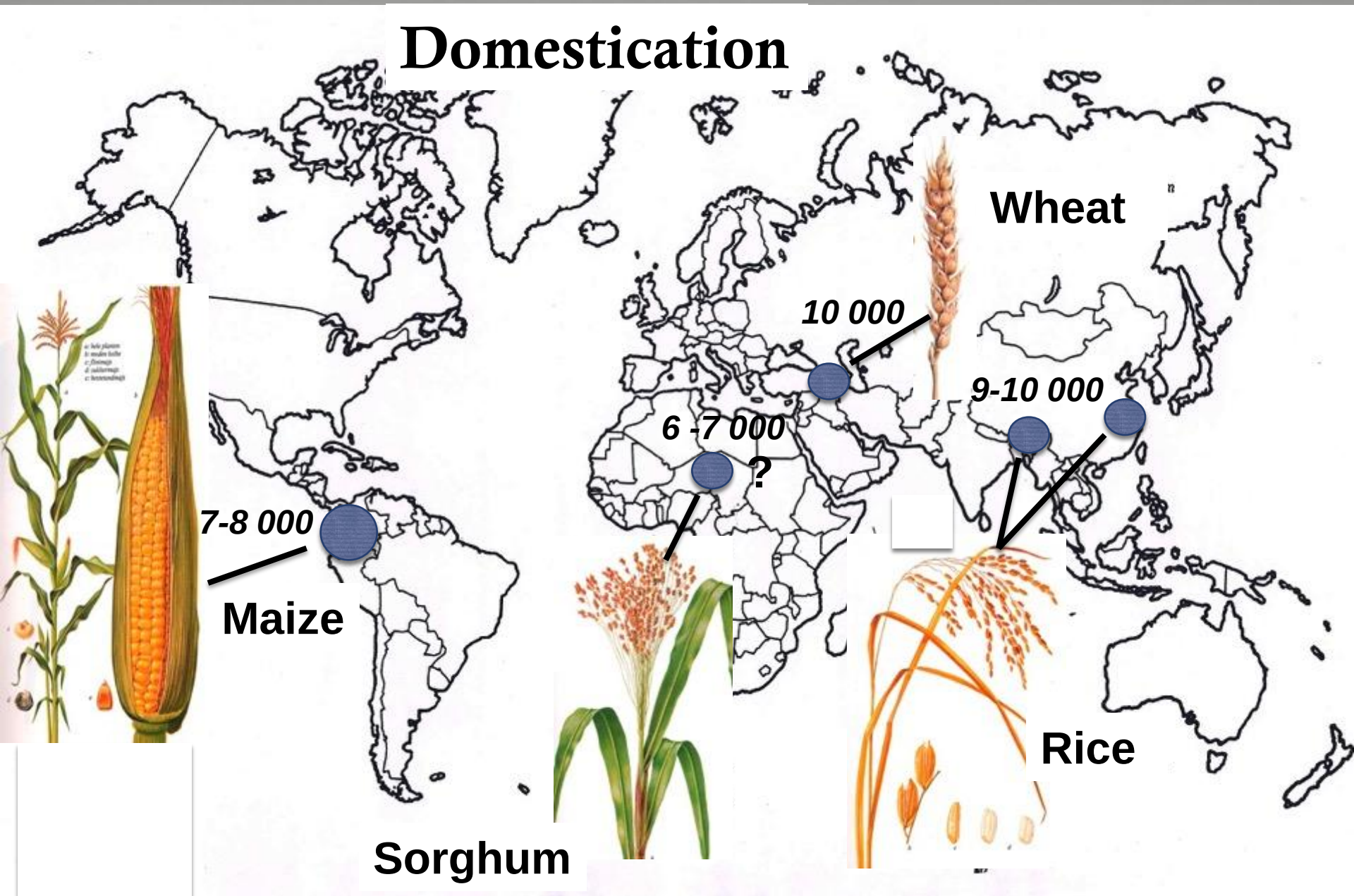
Roland von Bothmer

NordGen

Svalbard Global Seed Vault

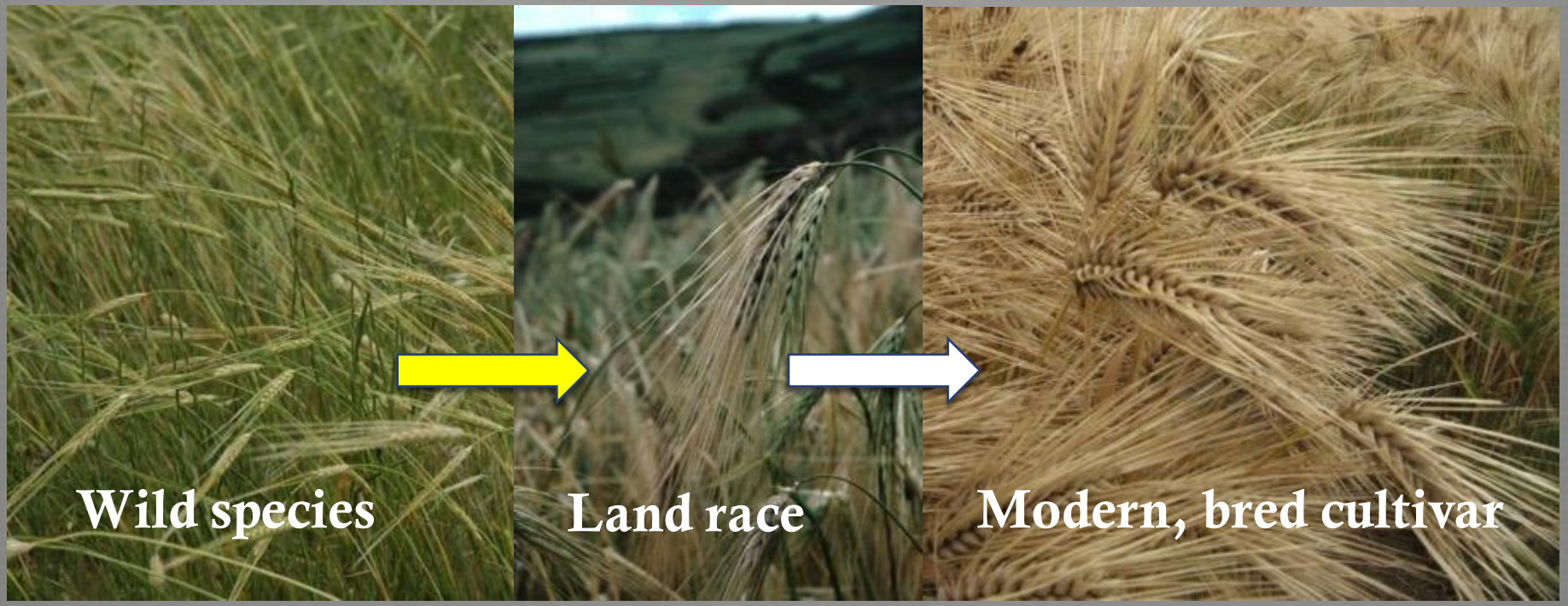
HOW DID THE CROP DIVERSITY DEVELOP?

Grasses became cereals (years BP)



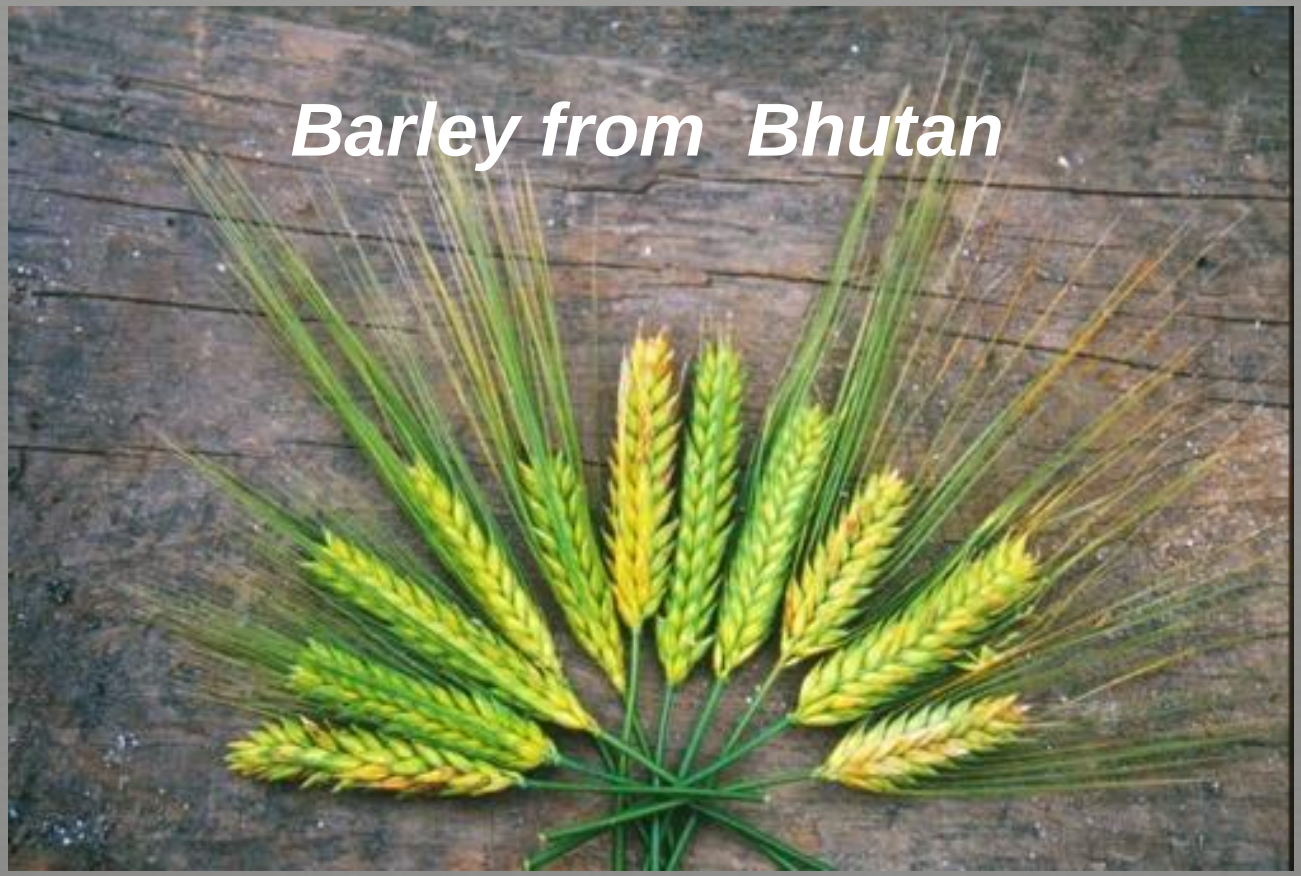
DOMESTICATION – from a wild habitat to an agricultural ecosystem – a rapid genetic shift

Hordeum vulgare: cultivated barley



MIGRATION and ADAPTATION

Gradual development;
minor genetic changes over a longer period



Many species show an extreme adaptation!

–

and numerous landraces

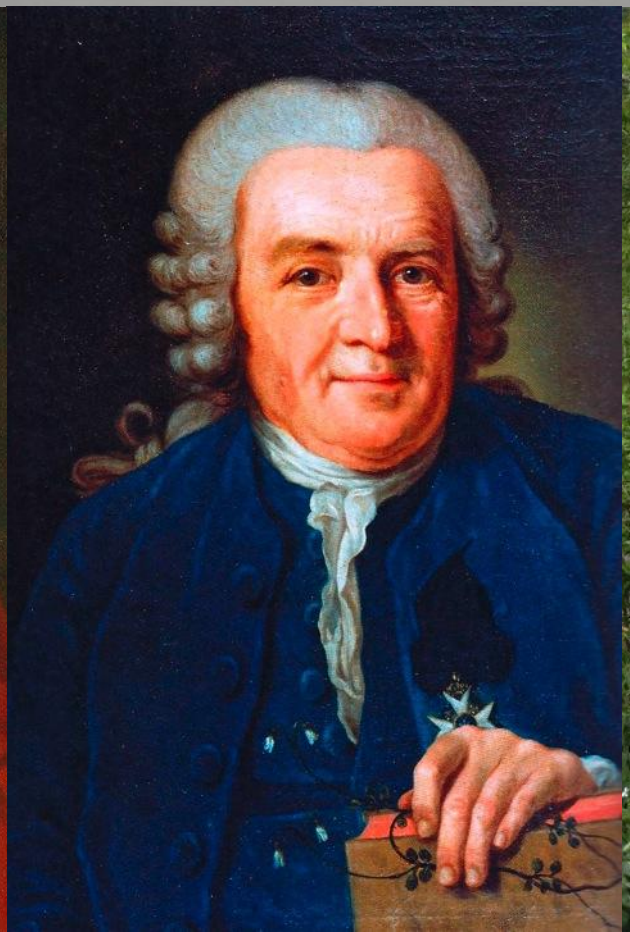
Wheat field in Northern Pakistan at 4000 m

1492 – the turning point for gene exchange!

Christopher Columbus' oversea journeys started the new era of transfer of biological material at a large scale, sometimes called

"Ecological Imperialism"

Linnaeus -
the scientific icon of Sweden was obsessed by the utility of plants



PLANT HUNTERS were sent out

Thunberg in Japan

Forsskål in
”The Happy Arabia”

Everything found was collected ....

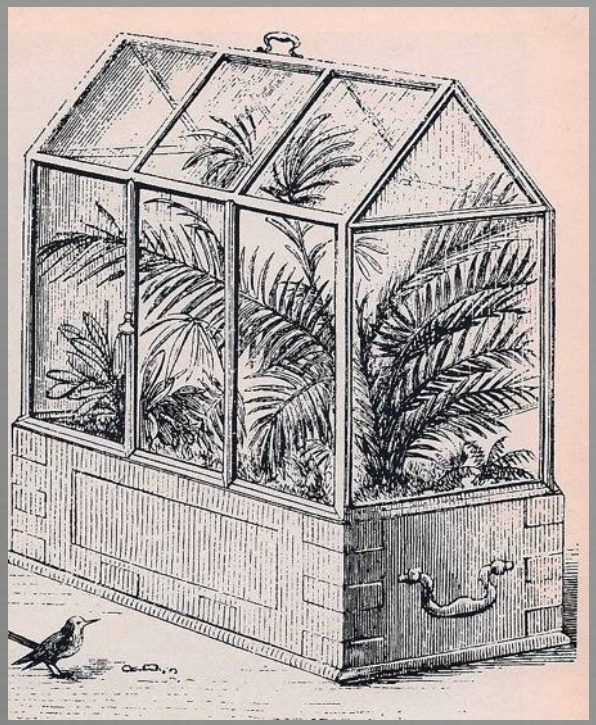
Pineapple

Bread fruit

Strelitzia

Sunflower

..... and shipped to Europe



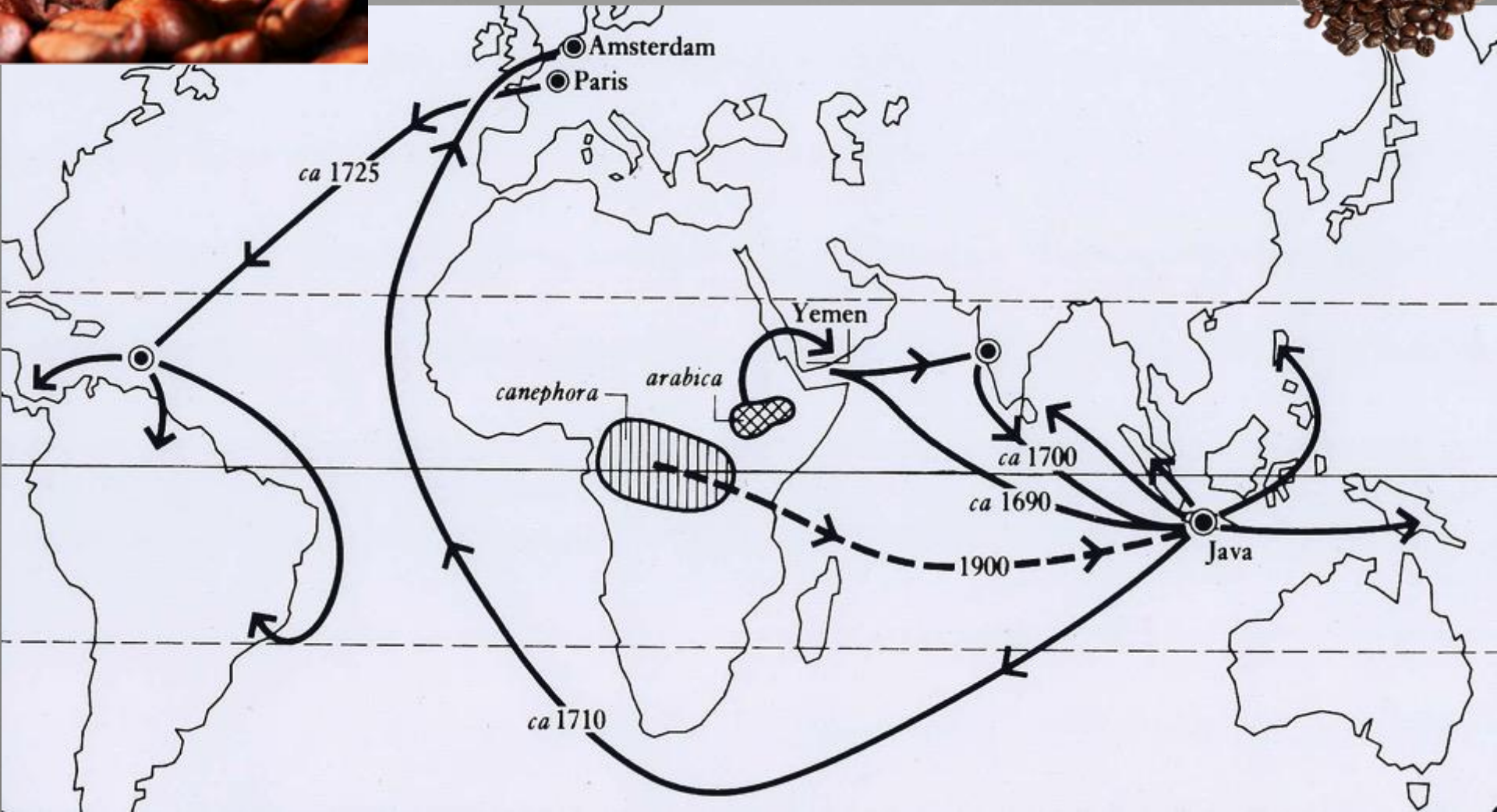
The Wardian Case

Banks and Solander in Australia

Botanical Gardens became the first ”gene banks” holder of exotic biological material

Kew
ROYAL BOTANIC GARDENS

Migration of coffea – an intricate story

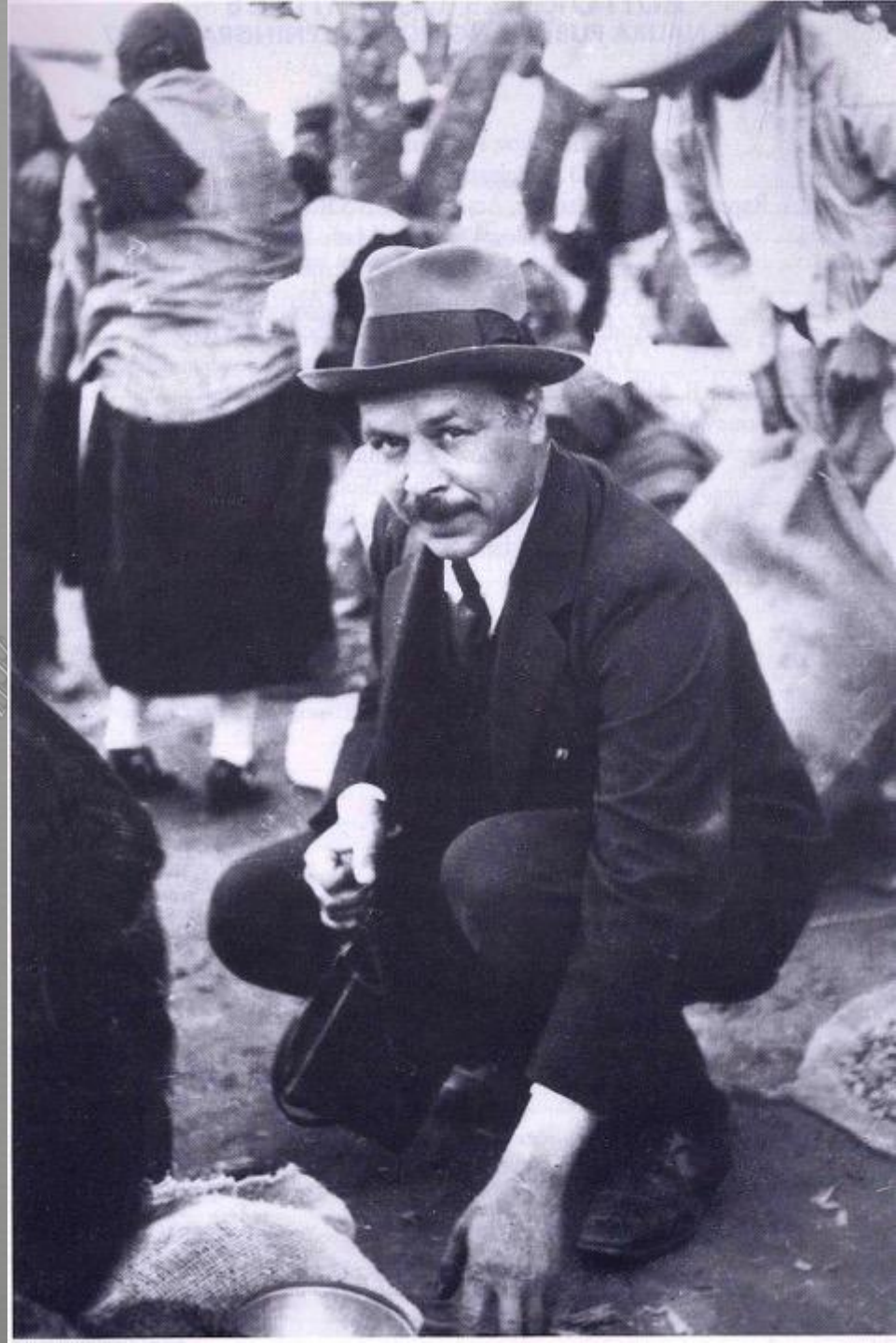


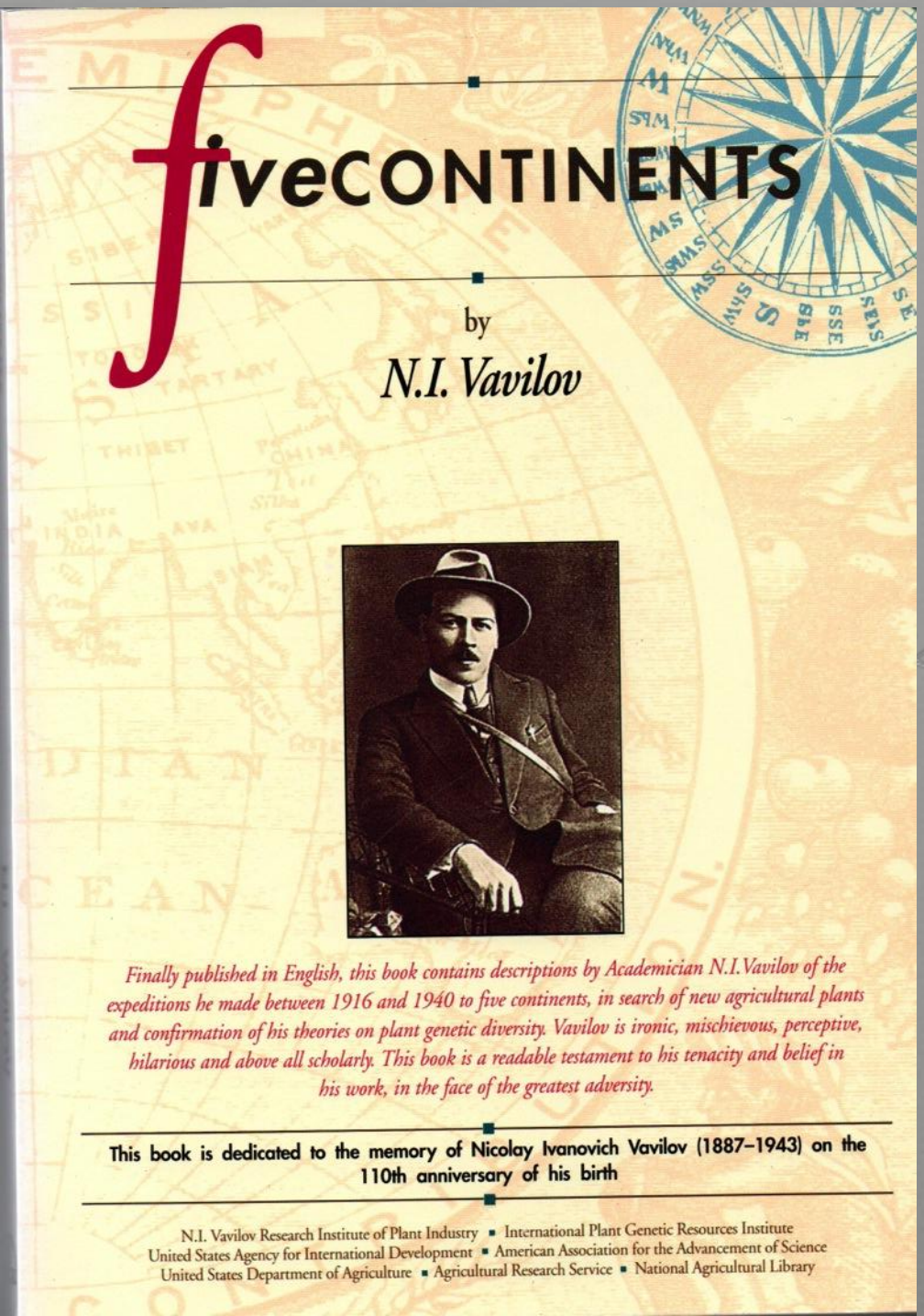
The last phase of diversity creation

Modern plant breeding

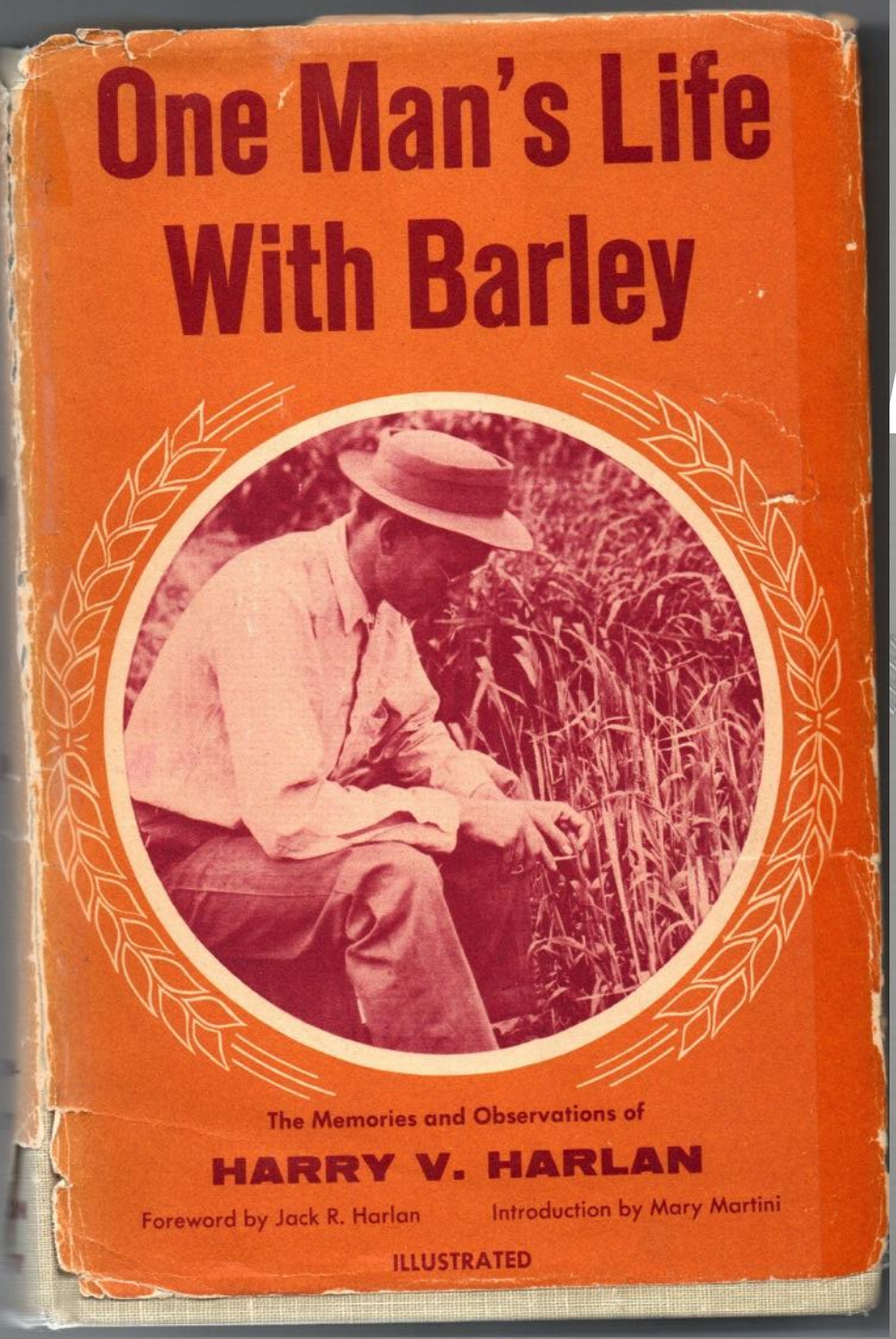
THE GENE BANK CONCEPT DEVELOPS IN THE EARLY 1900s

N. I. Vavilov
– a pioneer





Vavilov's expeditions – an interesting and important publication



An American pioneer: *HARRY HARLAN*

Harlan made major collections in S America, Africa and Asia

–

basis for the USDA genbank

Where is the genetic diversity today?

- ***in nature***

Where is the genetic diversity today?

- ***clonal archives***

Where is the genetic diversity today?

- ***gene banks***

Where is the genetic diversity today?

- *”old” genes are present in new cultivars*

Where is the genetic diversity today?

- ***in the freezers and trials of the breeders***

Where is the genetic diversity today?

- *in (few) land races*

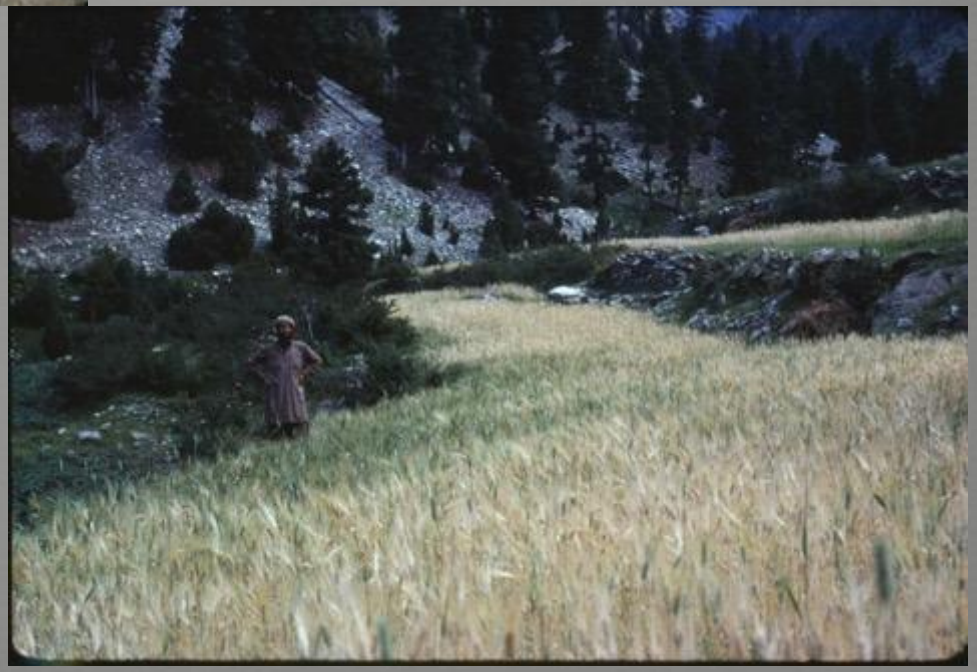
… but old land races disappear in an alarmering degree!

-

GENETIC EROSION is a reality!

Collecting in remote areas can be tough – but is often rewarding

Landraces in Pakistan

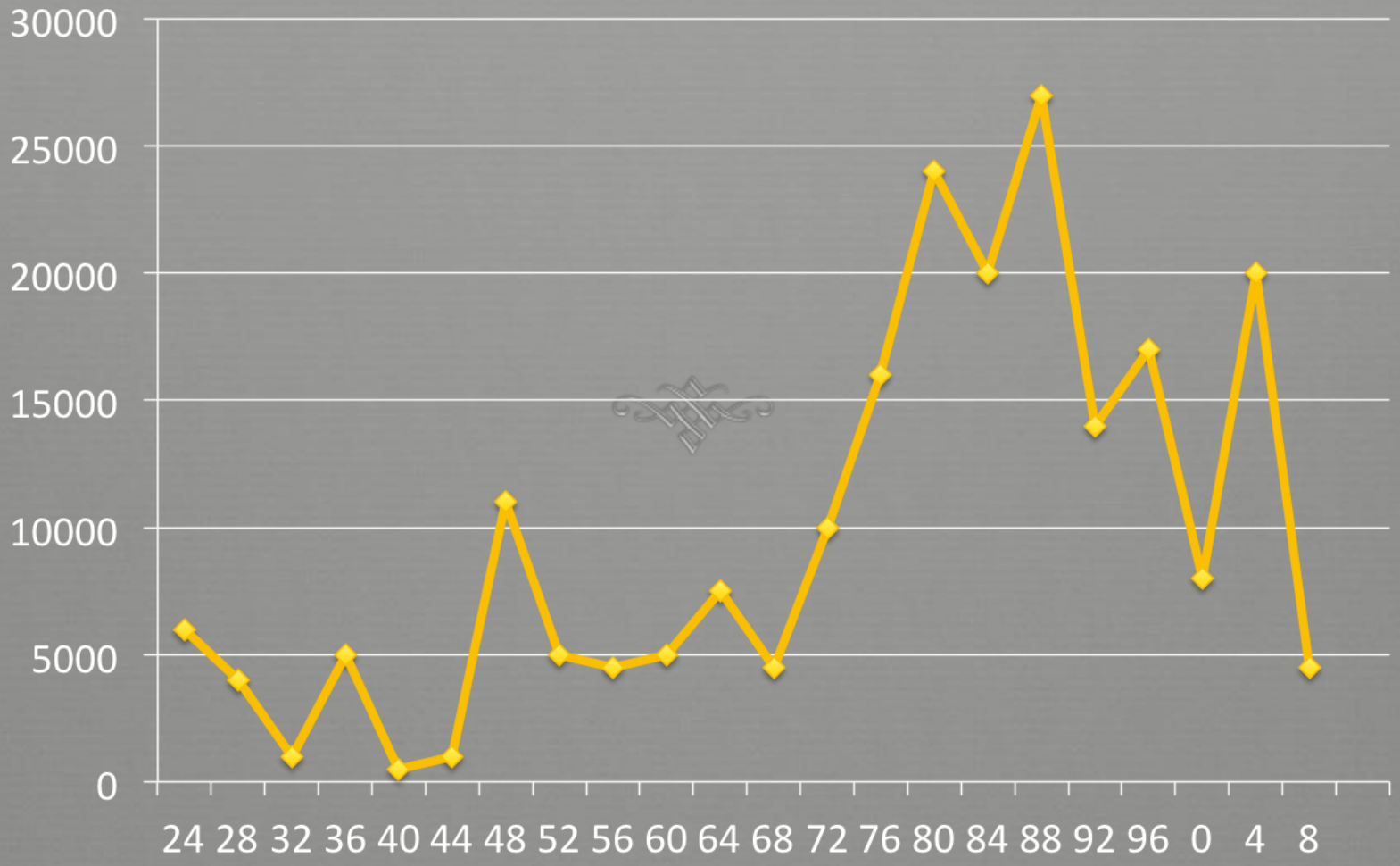


…. sometimes you are too late!

Collection is an ongoing business

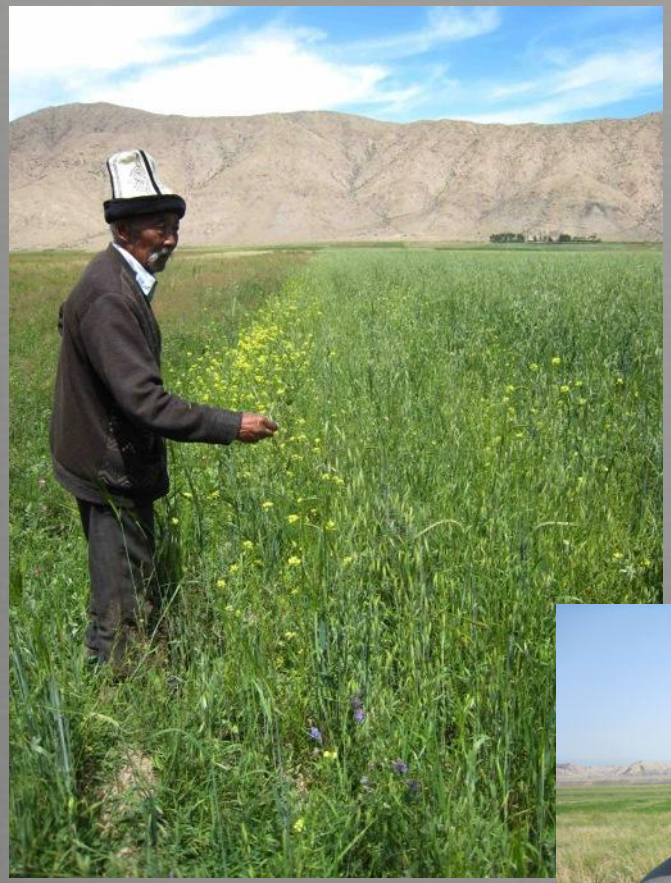
Collecting *wild barley* in China

Collections (no of accessions per year) 1924 - 2008



State of The World 2010

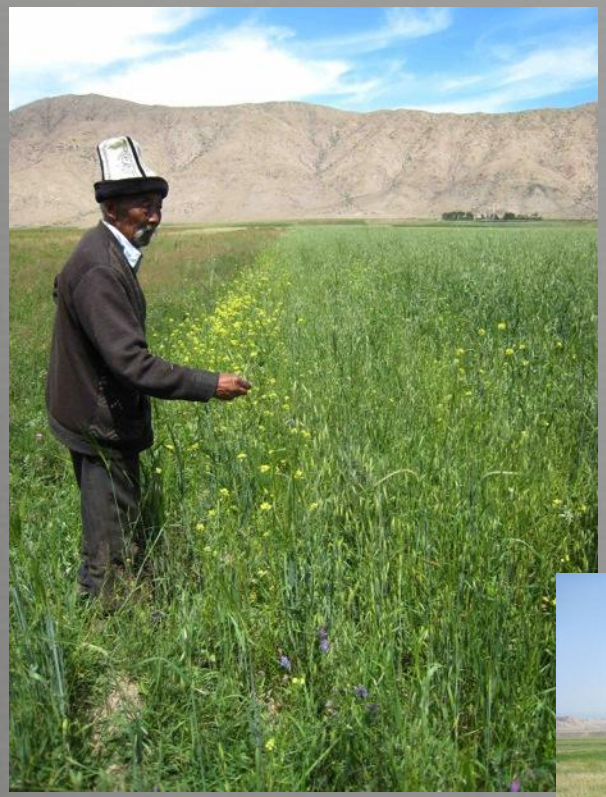
A SAD STORY OF GENTIC DIVERSITY!



Collecting in Kyrgyztan

2008

CAN ”NEW” DIVERSITY BE CREATED??



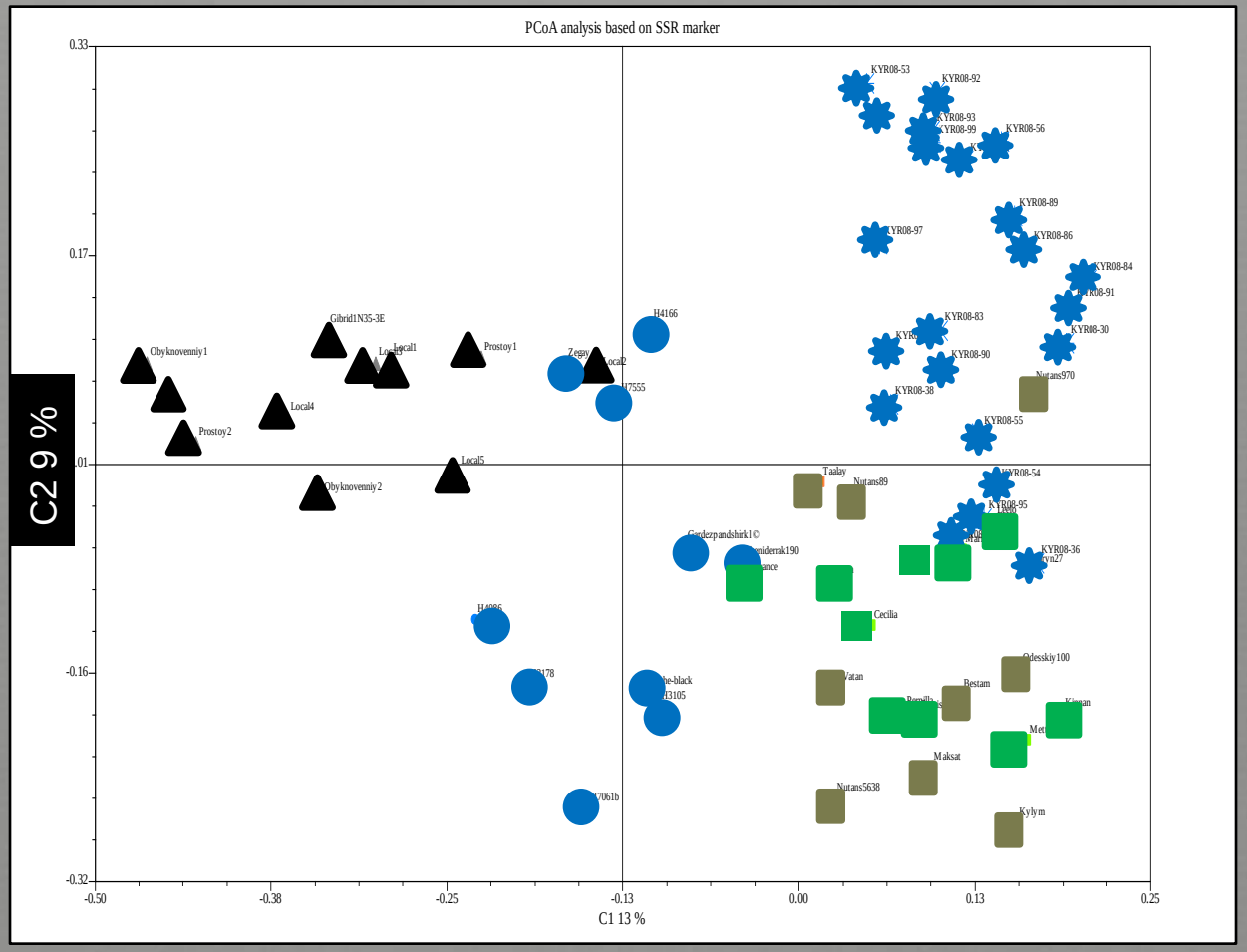
Background

Country information

Land Area: 198,500 sq km

The variation is very large – is it a landrace?

PCoA analysis of Kyrgyz material



✳ FMPs, ■ Kyrgyz cultivars, ■ Nordic and Baltic cultivars, ▲ Russian accessions, ● accessions from Afghanistan, China and Pakistan

Tortkyol

Kapacy

Image © 2011 TerraMetrics
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Image © 2011 GeoEye
© 2011 Mapabc.com

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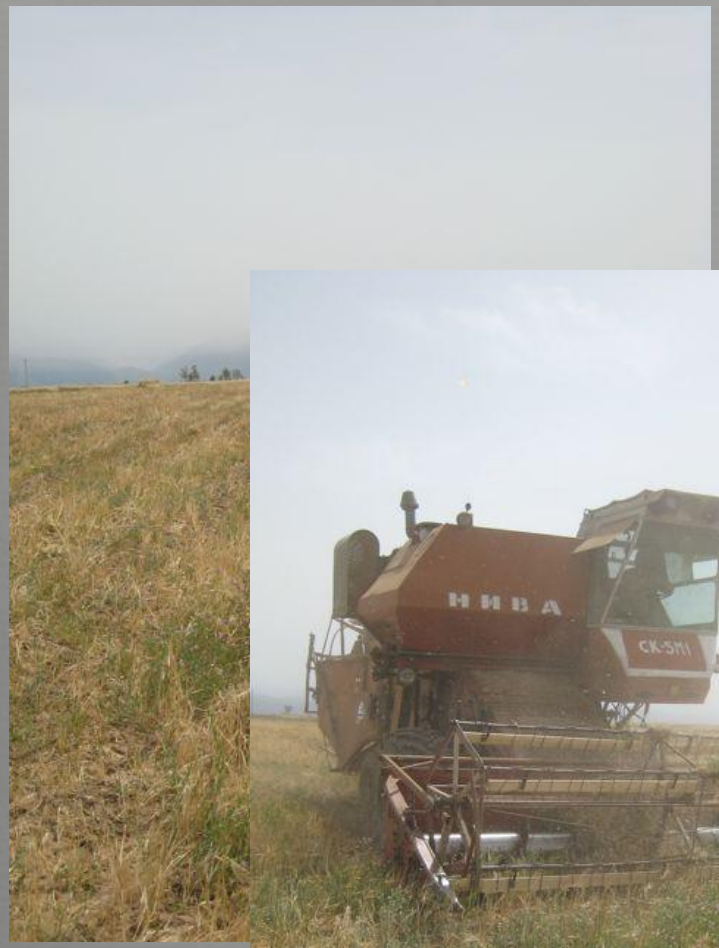
We came in the middle of the harvest



We came in the middle of the harvest

What was the harvest?

0.5 t/ha!

Reason:
Mixtures caused by *POWERTY*!!!!

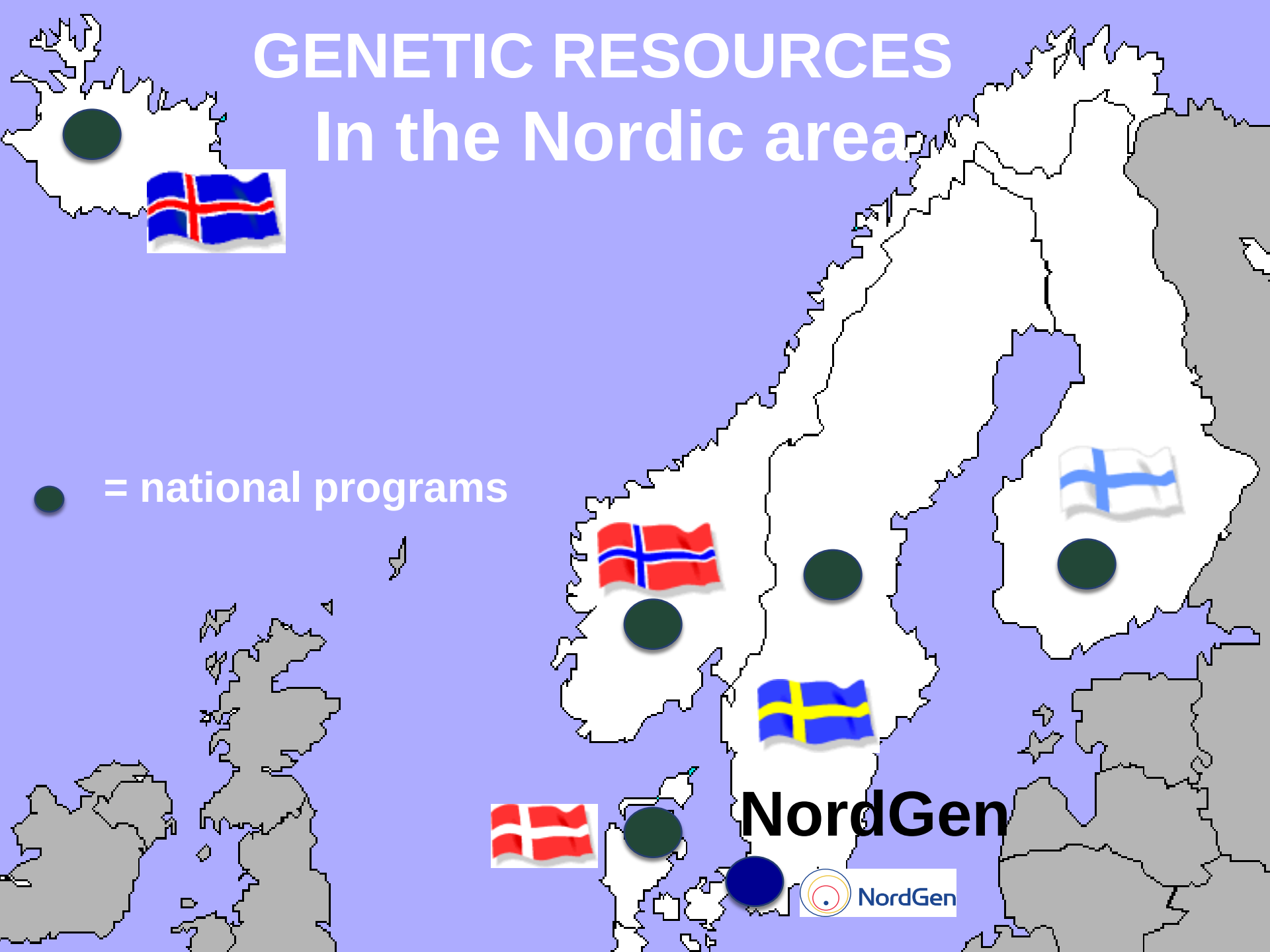
WHAT IS A GENE BANK?

The Gene Banks are ”low technology”
- dry seeds in a freezer!!
The value lies in the information!





GENETIC RESOURCES
In the Nordic area



NordGen

NordGen Plants

- **Active collection –**
  Alnarp, Sweden

- **Base collection –**
  Årslev, Denmark

- **Security collection -**
  Svalbard, Norway

NordGen

NordGen is a Nordic institute for the conservation and sustainable use of plants, farm animals and forest trees

NordGen´s basic goal is to secure genetic diversity for agriculture, horticulture and forestry in the Nordic countries



NordGen

Conservation approaches at NordGen

The seed gene bank

the majority of our collection

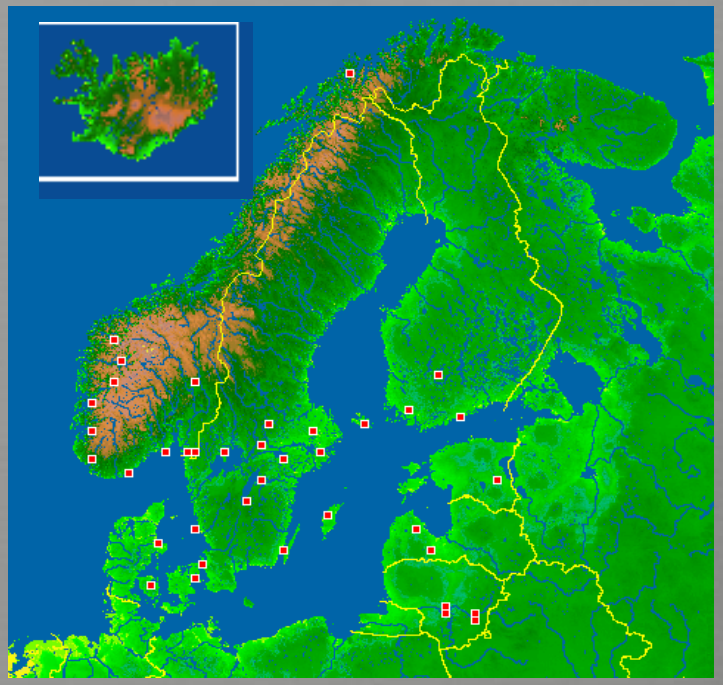
In vitro

conservation of potato

Field gene banks

Each country is responsible for the conservation of vegetatively propagated plant material.

NordGen is responsible for storing and distributing documentation about the material in the national collections.



Locations of clonal archives (including Baltic area)





NORDIC GENETIC RESOURCES

Seed propagated material

NORDIC GENETIC RESOURCES

Vegetatively propagated material

cherries

horse radish

apples

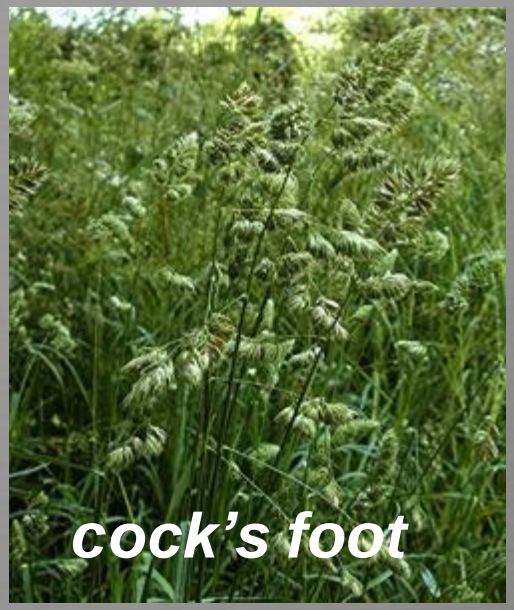
Black currants

potatoes

Native crops

Festuca pratensis

Poa pratensis

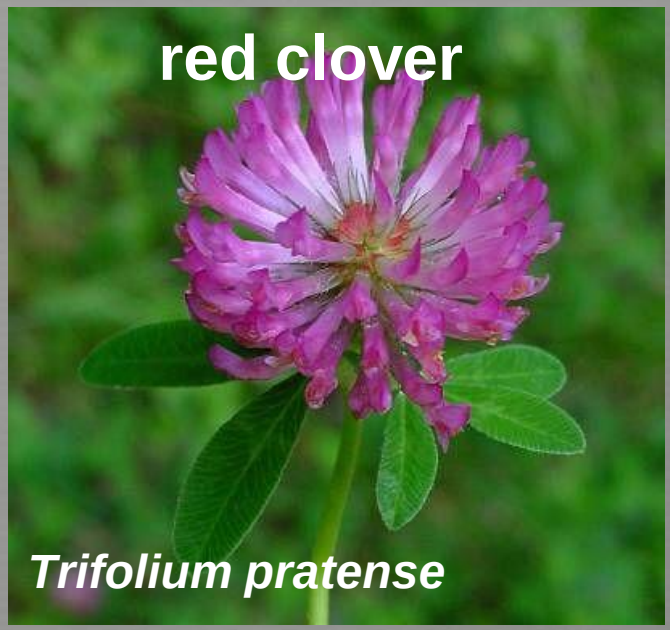


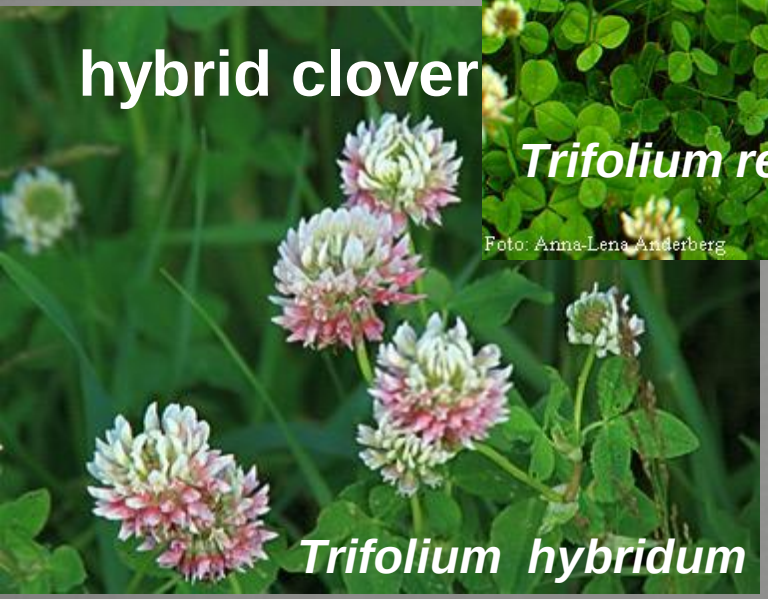
Dactylis glomerata

Phleum pratense

Forage grasses!

Native crops





Forage legumes

Material

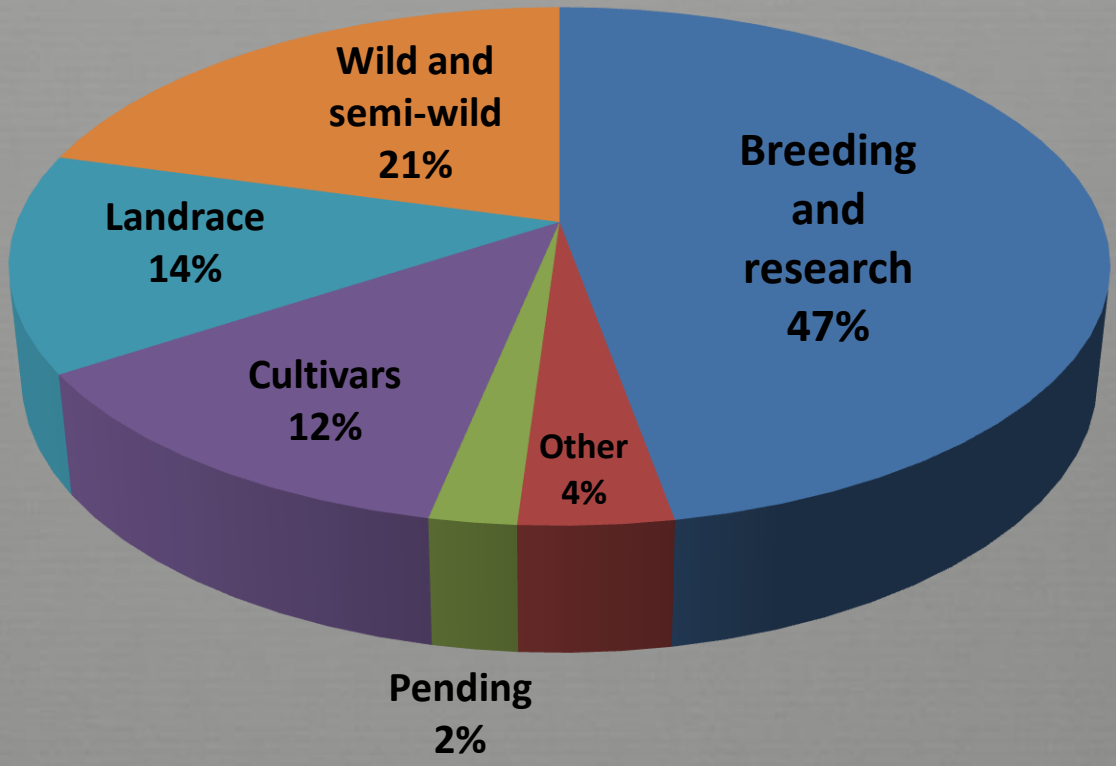
"of Nordic origin or of Nordic relevance"

Plant group	No. accs.
• Cereals	20 000
• Forages	4 800
• Fruits & berries	15
• Potato	80
• Industrial crops	5 500
• Ornamentals	230
• Med. plants and spices	350
TOTAL:	~32.500




NordGen

Type of material: the whole collection



NordGen

Barley genetic stock collection
> 13 600 accessions

No of acc.	*Types of Genetic Stocks*
10776	Mutant collection
980	Bowman near isogenic lines (NIL)
685	Translocation lines
58	Duplication lines
242	James Mac Key near isogenic lines (NIL)
176	*H. bulbosum* introgression lines

NordGen

Lactuca collection
(Svalöf Weibull AB)

- Wild material, mainly *Lactuca serriola*, collected in Sweden
- 300 accessions, screened for resistance to *Bremia lactucae*
- 80 resistant acc found, used for crosses with *L. sativa*
- DNA studies (DNA landmark, Canada)

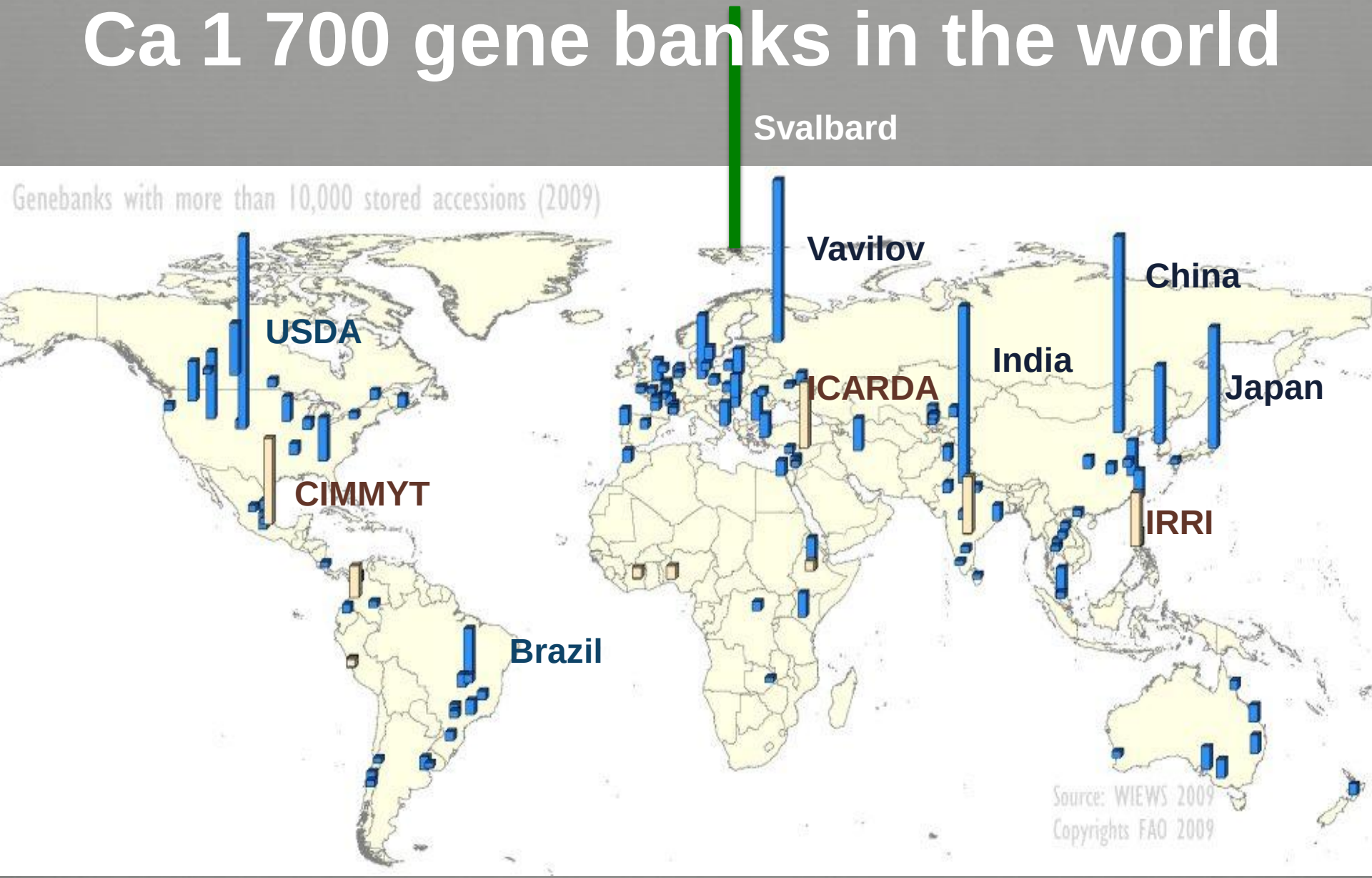
NordGen's Collection

Cultural Relict Plants –
plants that grow on historical sites having potential to be survivors from that time

Collecting missions with botanist and/or archaeologists

many *medicinal plants* *ornamentals* ~30 collects

Ca 1 700 gene banks in the world

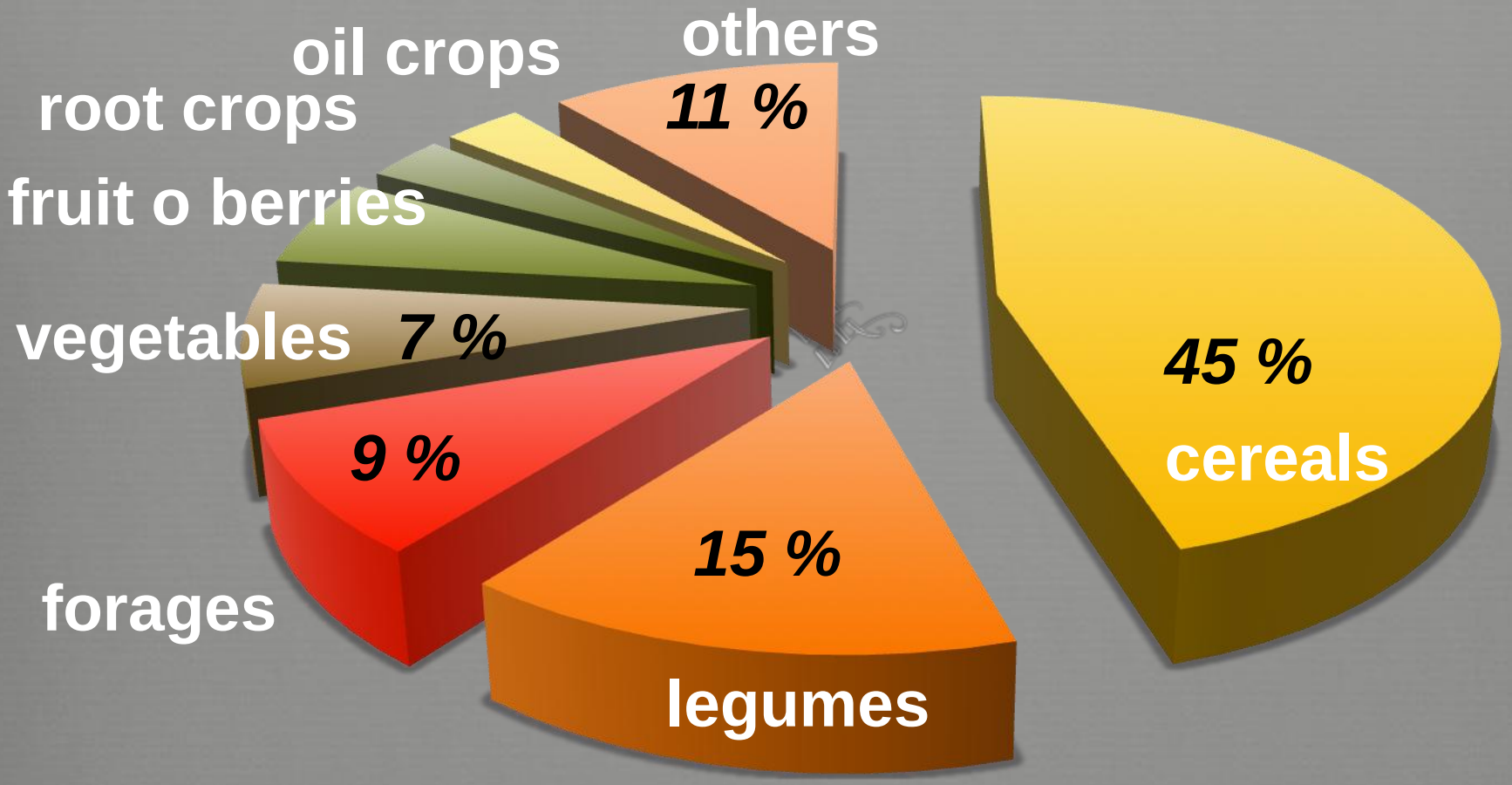


State of The World 2010

Gene banks with > 10 000 accessions

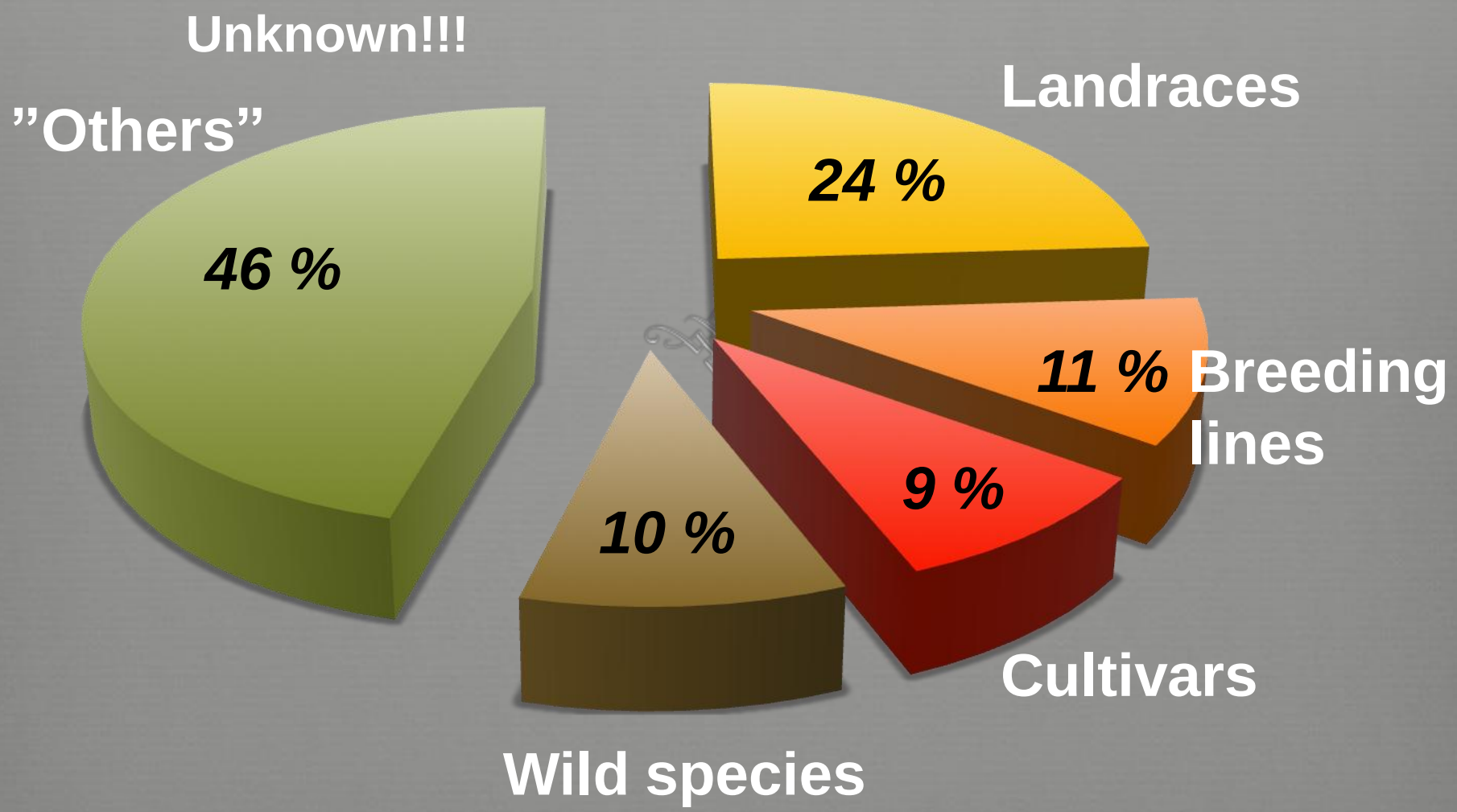
Accessions in gene banks of the world

totally 7.4 mill – unique ca 2.5 mill



Do we actually know what we have in the gene banks?

PGR in the world collections

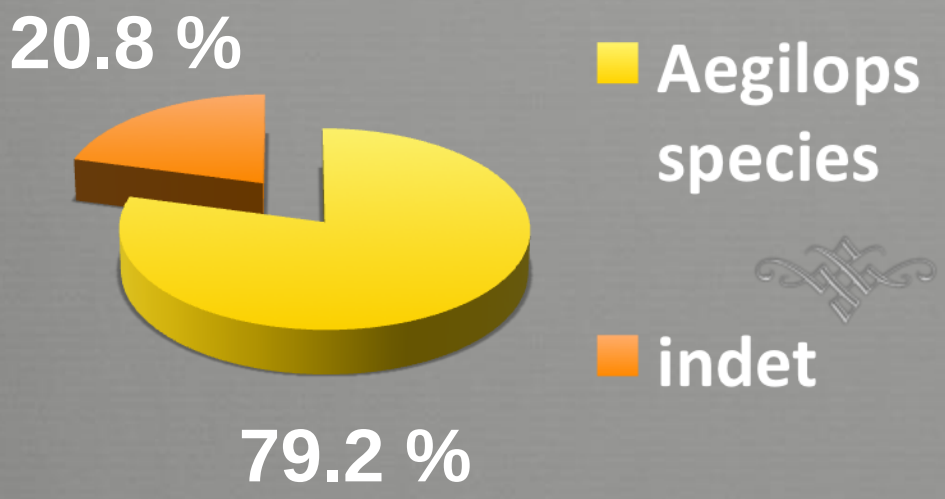


Aegilops in gene banks

Goatgrasses

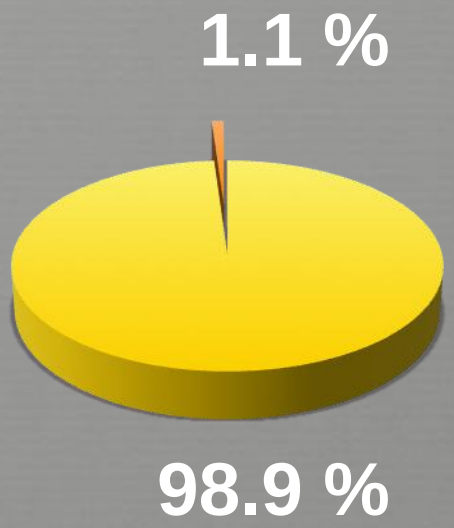
Aegilops in gene banks

WIEWS



41 species
42 273 accessions

SGSV



26 species
3 528 accessions *(8.3 %)*

Diversity in *Brassica* – a European story

Greek classic period B.C.

terminal buds

lateral buds

stem

leaves

stem & flowers

Inflo-rescence

cabbage

brussel-sprouts

kohlrabbi

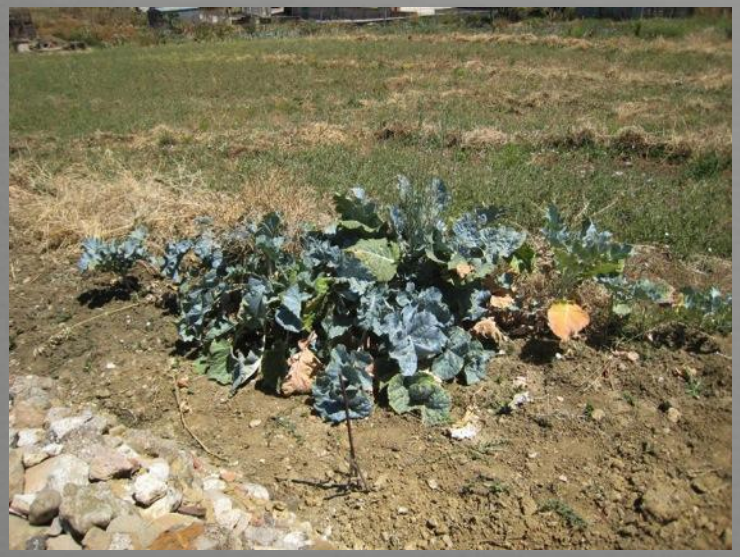
kale

broccoli

cauli-flower

BRASSICA in genebanks – A case study

WORLD	BRAS-EDB	EURISCO	SGSV*
102 213	**25 901**	**22 675**	**7 121**
	25.3%	*22.2 %*	*6.9 %*



- *Duplicates?*
- *Overlaps?*
- *Safety back-up?*

***Svalbard**

WILD *BRASSICA* (n=9) IN GENEBANKS

Collected material:

IBPGR missions in 5 countries in 1982 – 1988:

- **ESP, FRA, ITA, GRC, GBR**
- **~ 185 accessions of 9 species**
- **Available: 19 accessions of 2 species (16 GBR and 3 GRC)!!!**
- **No information on other accessions!!!**

From Noortje Bas, CGN

WILD *BRASSICA* (n=9) IN GENEBANKS

CONCLUSIONS:

- **Several collecting missions; availability is limited or badly known**
- **Number of collected/available samples is limited -** ***often seed collected from very few plants***
- **Material made available under different conditions**

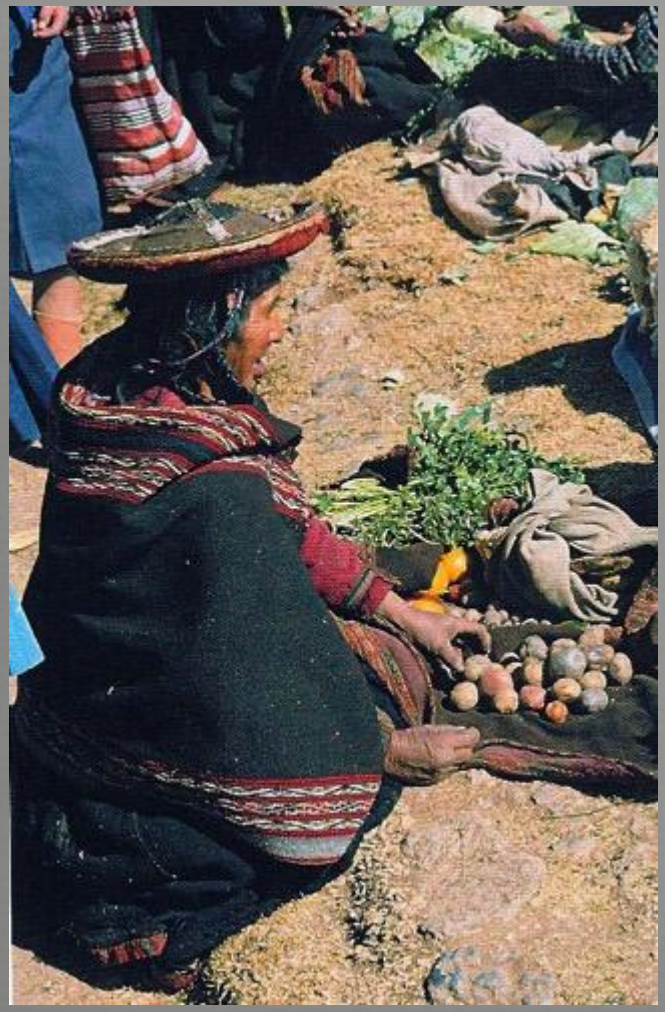
  In some collections: "Not to be used for breeding"

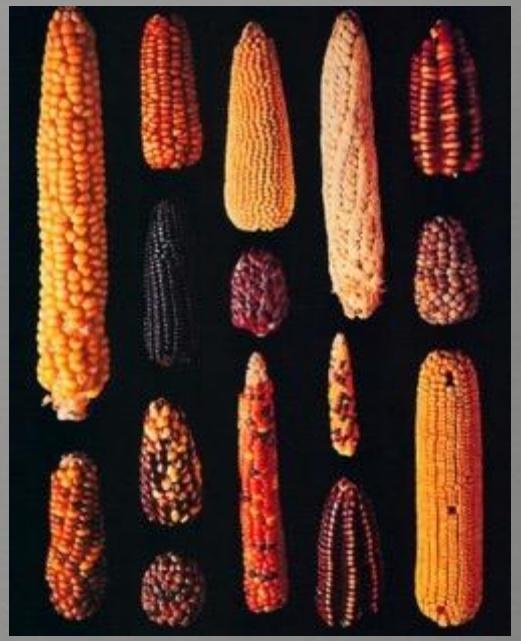
From Noortje Bas, CGN

CONSERVATION IN GENE BANKS
General conclusions

- Availability of genebank material often uncertain
- Genetic status of material rel. unknown
- Much material is not determined
- Safety back-up needs improvement
- Complementary collecting necessary (CWR)
- Different taxonomies used is a problem
- Databases are not fully compatible
- How many duplicates are there?

GENETIC DIVERSITY – of future importance





There are many threats to the gene banks of the world!!!

- Economic problems
- Corruption
- Equipment failure
- Wars and strides
- Nature catastrophies: landslides, tsunamis, flooding, eart h quakes

CORRUPTION!!!

Central Asia 2008

FLOODING!!

The Thai gene bank

ICARDA
Science for Better Livelihoods in Dry Areas

Aleppo, Syria

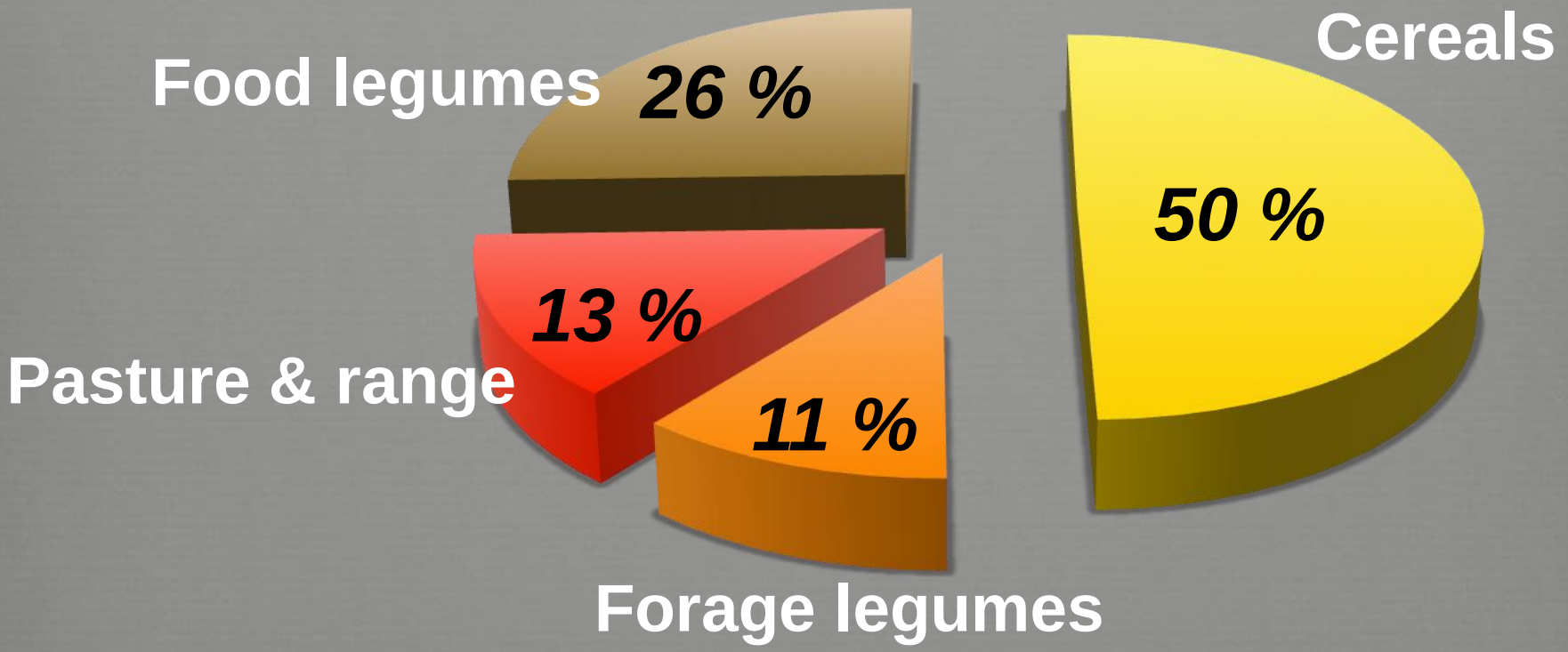
The war came….

CGIAR | Research Program on Dryland Systems

ICARDA
Science for Better Livelihoods in Dry Areas

Totally 148 000 accessions

(116 000 in Svalbard)

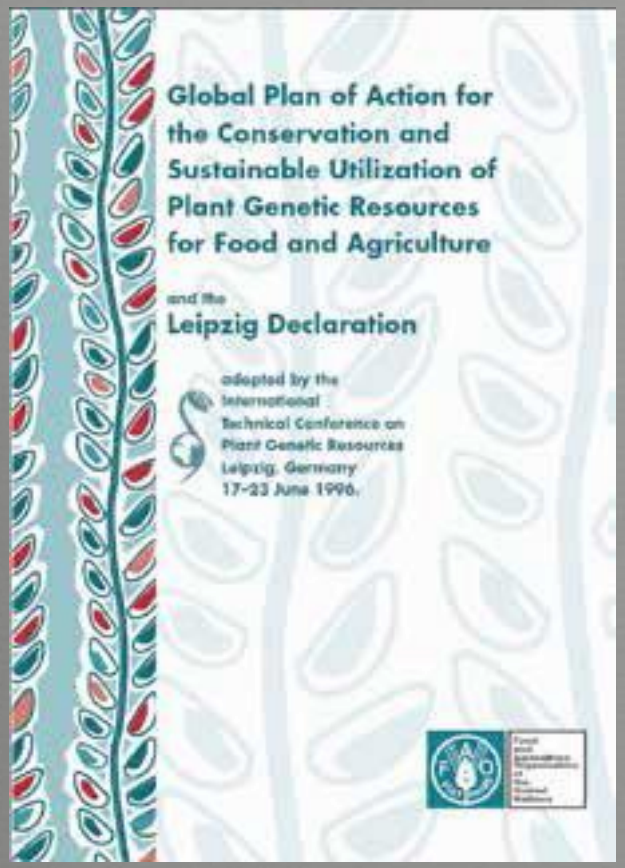


CIVIL WAR!

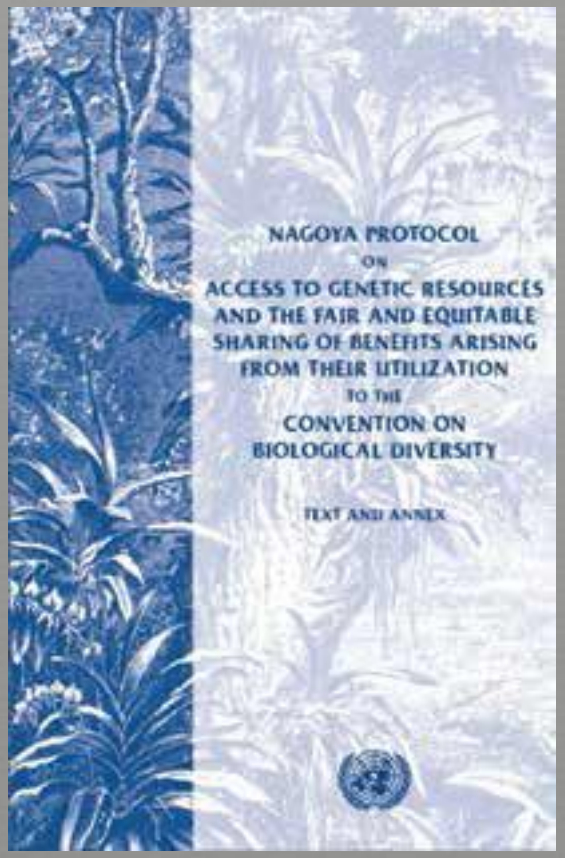
90 % of ICARDA's material is safety duplicated in the Vault

The ICARDA withdrawal of 40 000 accs in 2015 proved the need for the vault and that it is efficient and well funtioning when needed!

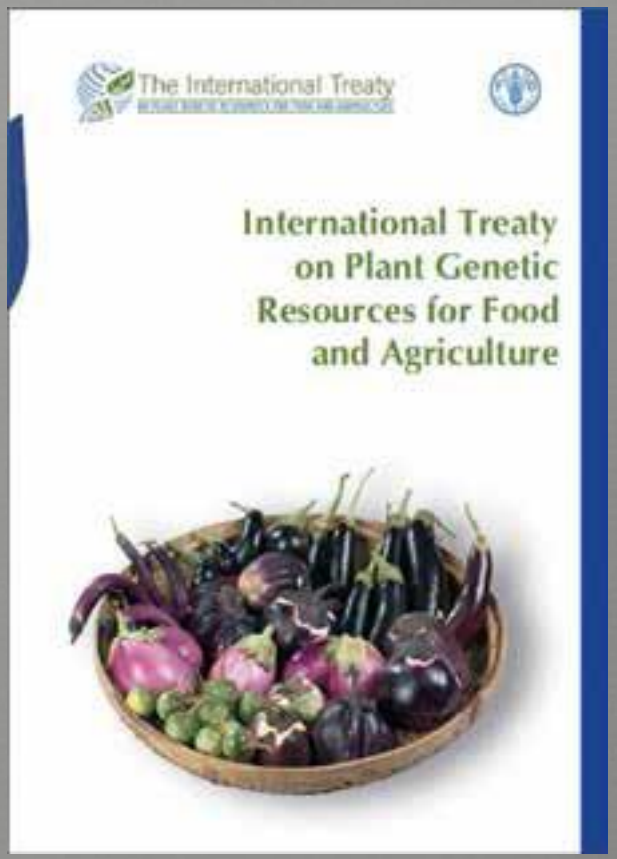
International agreements regulate the access to genetic resources



CBD
"Global Plan of Action"



"The Nagoya Protocol"



The International treaty of PGR
"The Treaty"

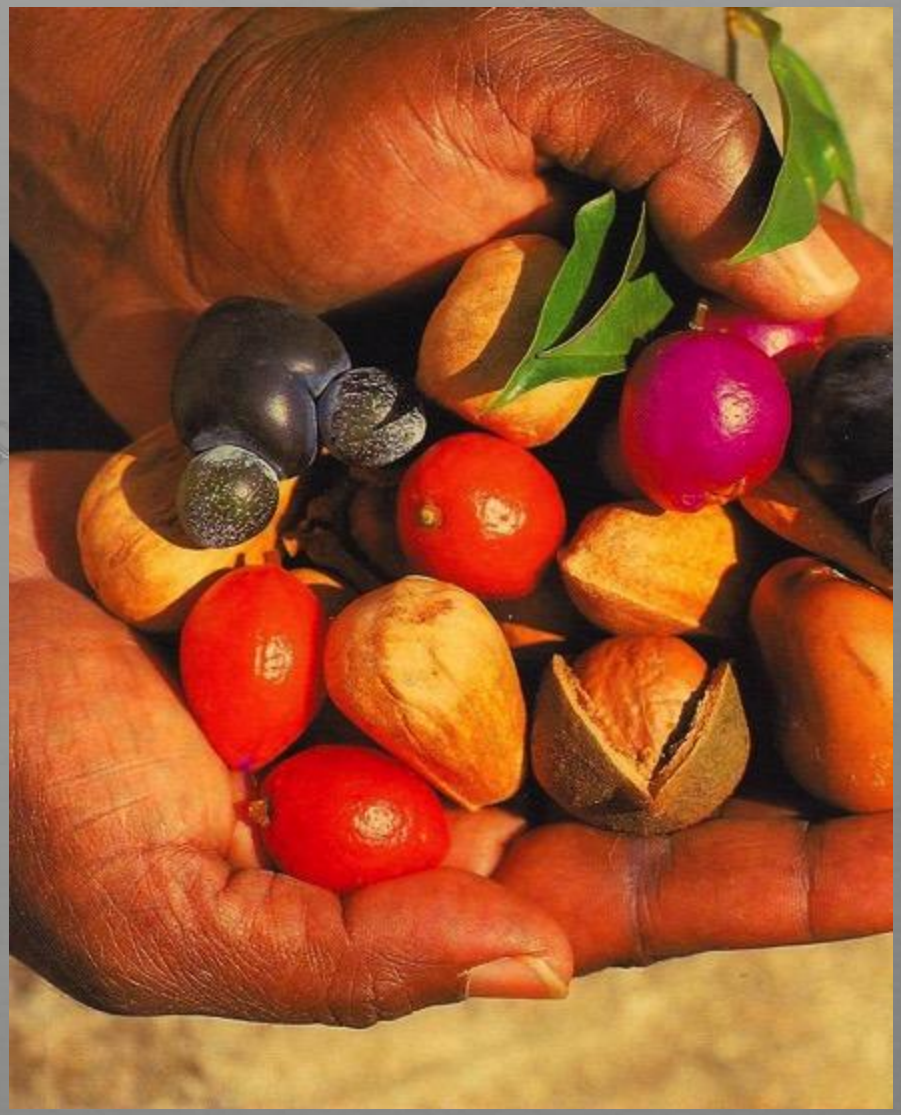
INTERNATIONAL DEVELOPMENT

- 1982 FAO, Comission of Plant Genetic Resources
- *1992 Convetion on Biodiversity (CBD/COP)*
- 1992-2004 FAO, The International Undertaking
- 1994 TRIPS Treaty (GATT, WTO)
- 1996 The Leipzig Declaration
- *2004 The International Treaty on PGR*
- *2010 The Nagoya Protocol*

What does the Rio Declaration say?

AGENDA 21, 15:3:

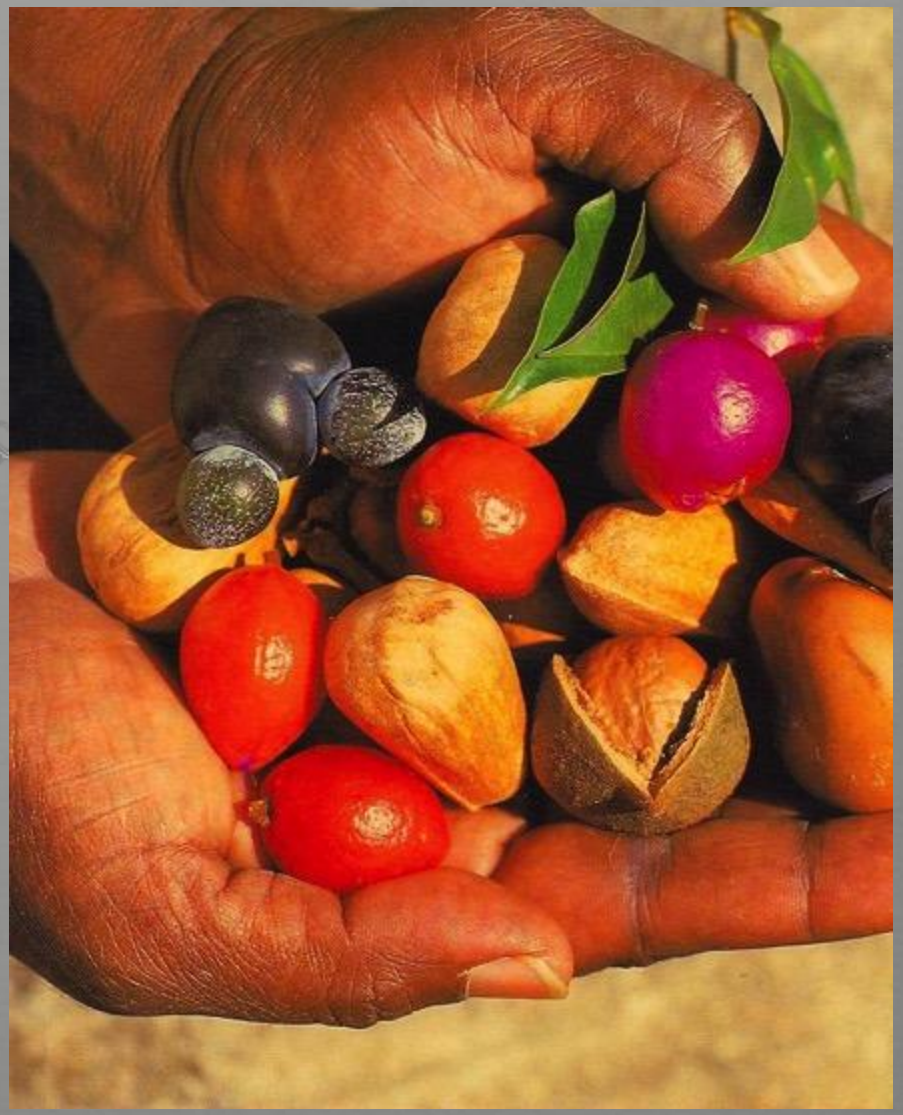
*”..countries have **souvereign rights** ...to their own genetic resources ”*



What does the Rio Declaration say?

AGENDA 21, 14:57:

”… sharing of benefits of the results of research and development in plant breeding…”



International collaboration

- Future food security depends on diversity in our crops
- Gene banks are vulnerable for many threats
- International collaboration is necessary


Svalbard
74-81°
North 10-
35° East
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Image © 2007 NASA
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SVALBARD

The ultimate conservation!

NordGen had its safety duplicate set in an abandoned coal mine at Svalbard in the middle of the 1980s

Vision

A global security net

The Svalbard Global Seed Vault shall be the *most secure back-up storage* for a global system of *ex situ* collections of diversity in crops

The Svalbard Global Seed Vault shall have the capacity to *store all unique* plant genetic resources in conventional genebanks of the world

Svalbard
Global Seed Vault

SGSV – Organization

- ***The Norwegian government***

  Owner, main funder and liable national authority

- ***Crop Trust***

  Partly funding the Seed Vault as part of the global conservation system

- ***NordGen***

  Responsible for management & operation

- ***Statsbygg***

  Responsible for service and continuous surveillance

- ***International Advisory Council***

  Oversees the operation

Svalbard Global Seed Vault

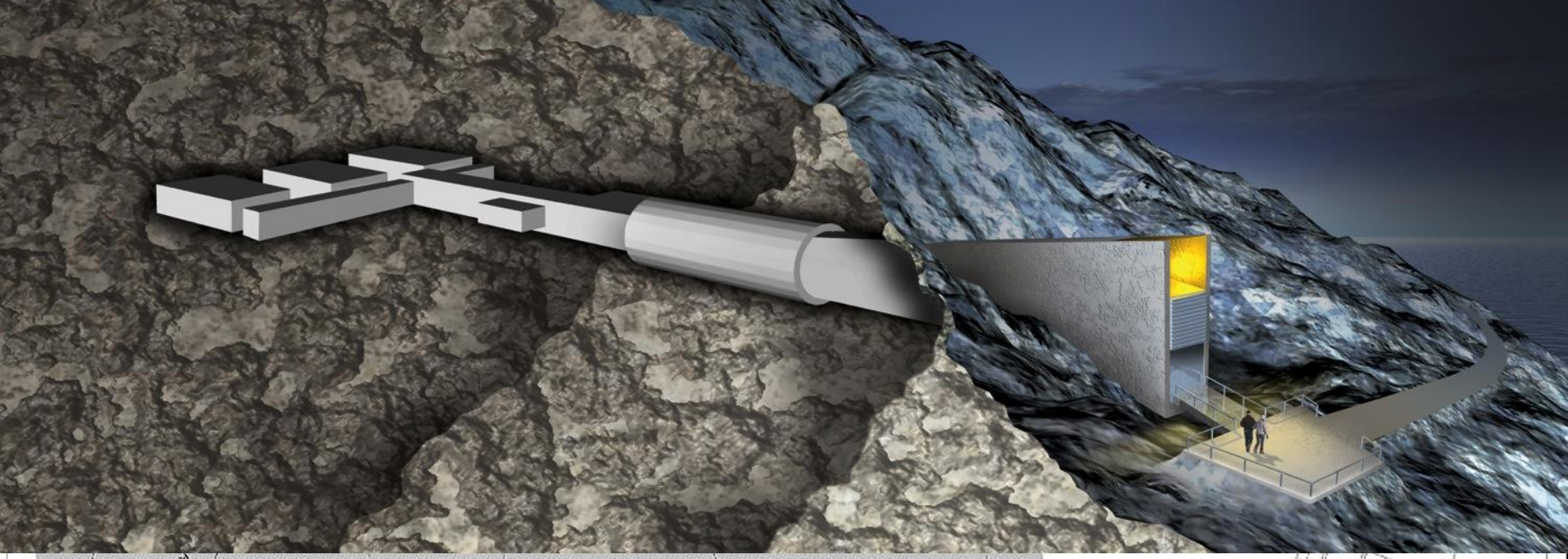
Standard Deposit Agreement

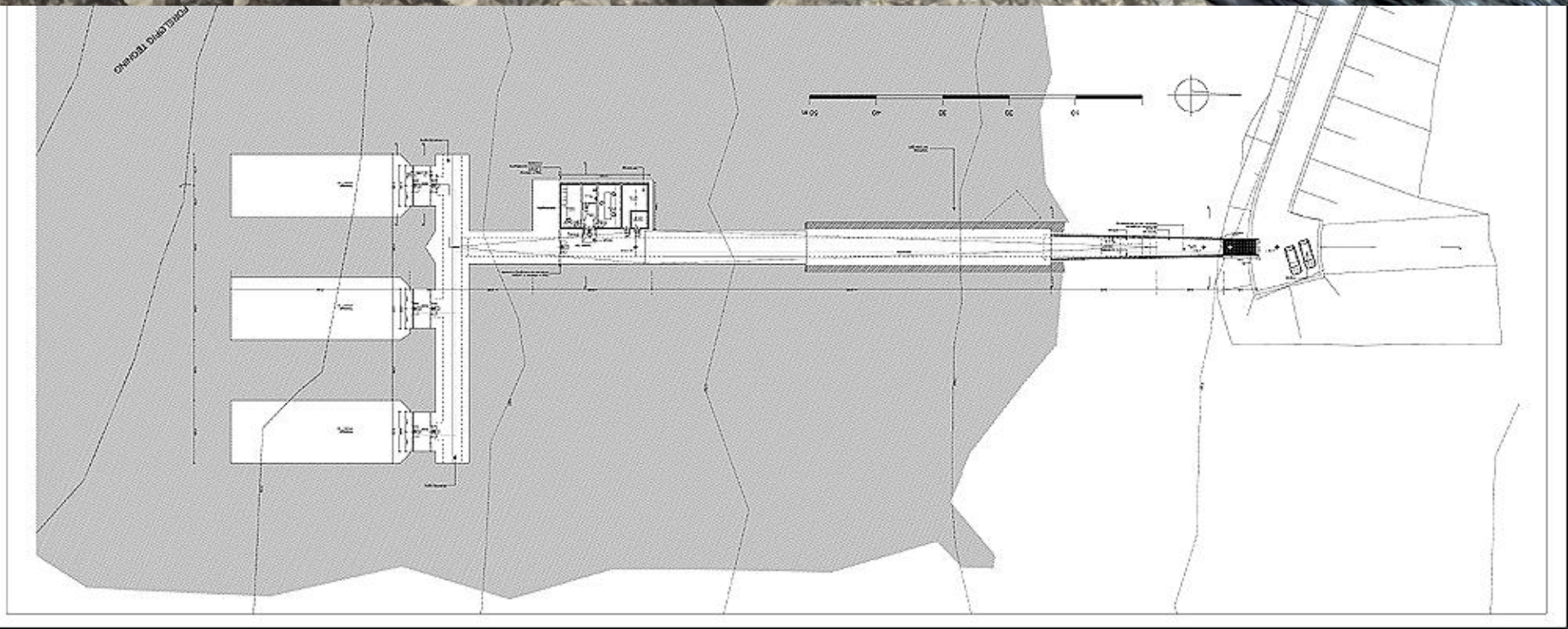
- No transfer of legal ownership
- Safety duplicates can only be returned to depositing genebank
- Deposit is consistent with relevant international law (CBD, ITPGRFA)
- Deposit is free of charge
- ”Black box” handling
- Information in an open database
- Viability monitoring and regeneration of original accession remains responsibility of the depositor

NordGen

The Structure

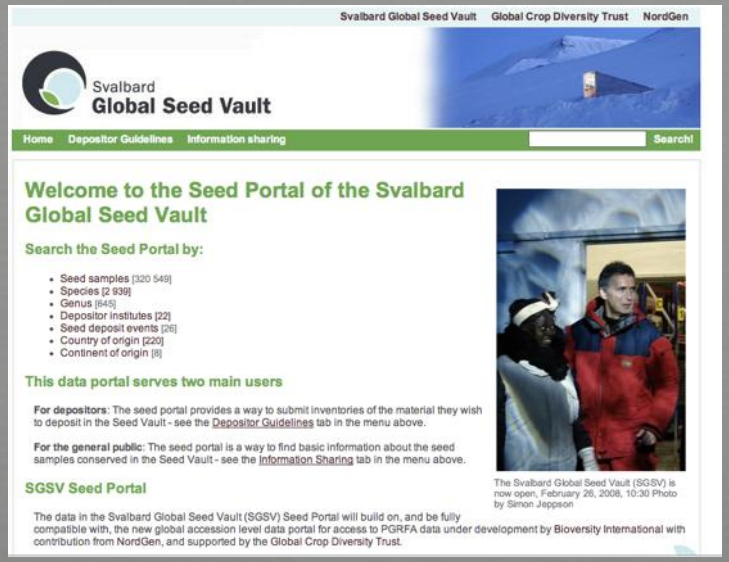
- Storage halls embedded in solid rock – 120 m into the mountainside
- 130 m above sea – above worst case climate change scenario for ice melting
- Geologically stable location
- Temperature maintained at -18°C
- Permafrost provides natural freeze guarantee at -4 °C in the case of equipment failure
- Monitoring and surveillance with gas- and temperature-detectors and security camera





Material in *The Global Seed Vault*
18 November, 2016

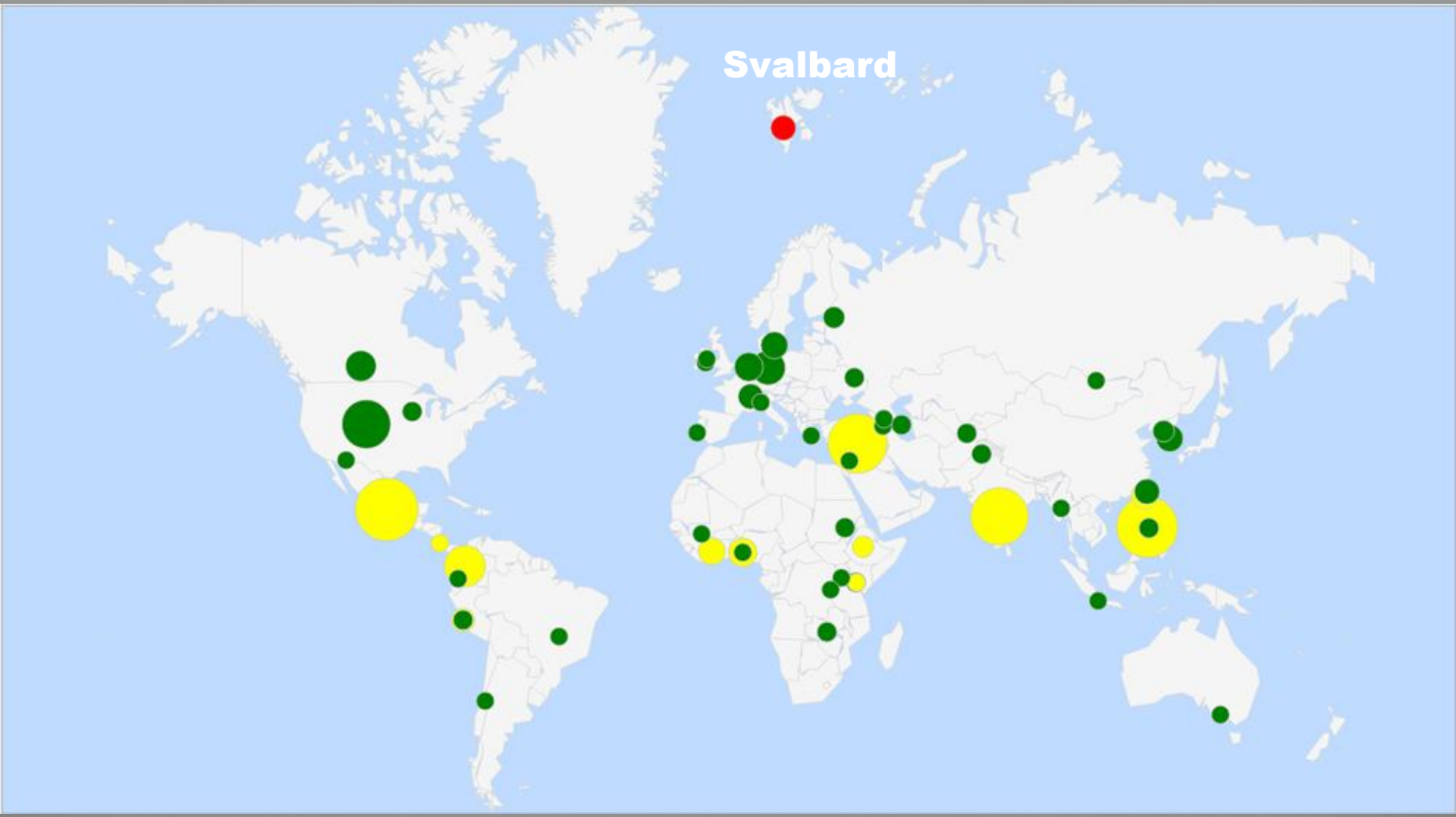
Countries: 234
Genera: 985
Species: 5 403
Accessions: 880 837



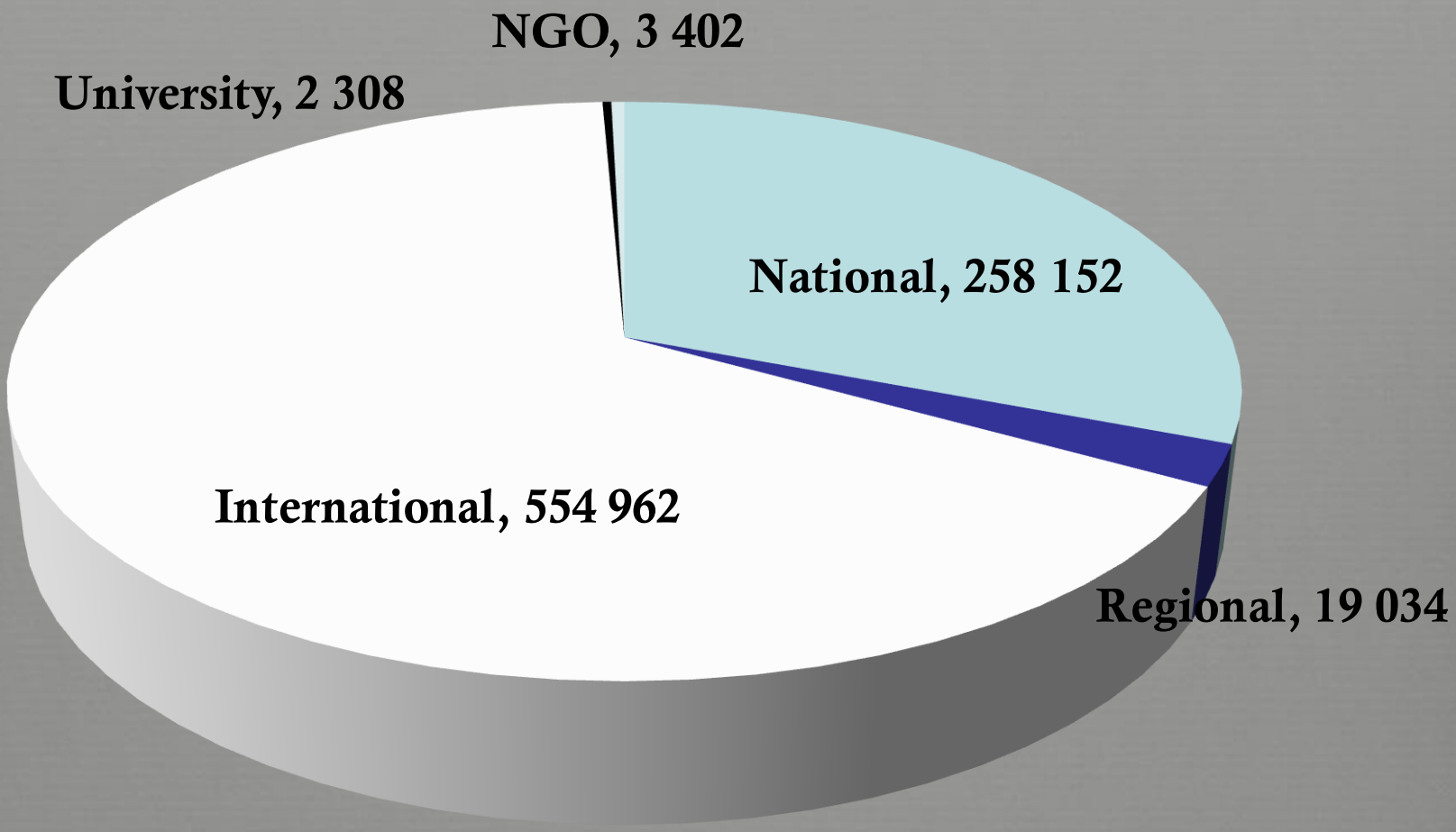
Status in The Vault

½ to 1/3 of all unique seed samples of crops are conserved in The Vault

Depositors in The Seed Vault

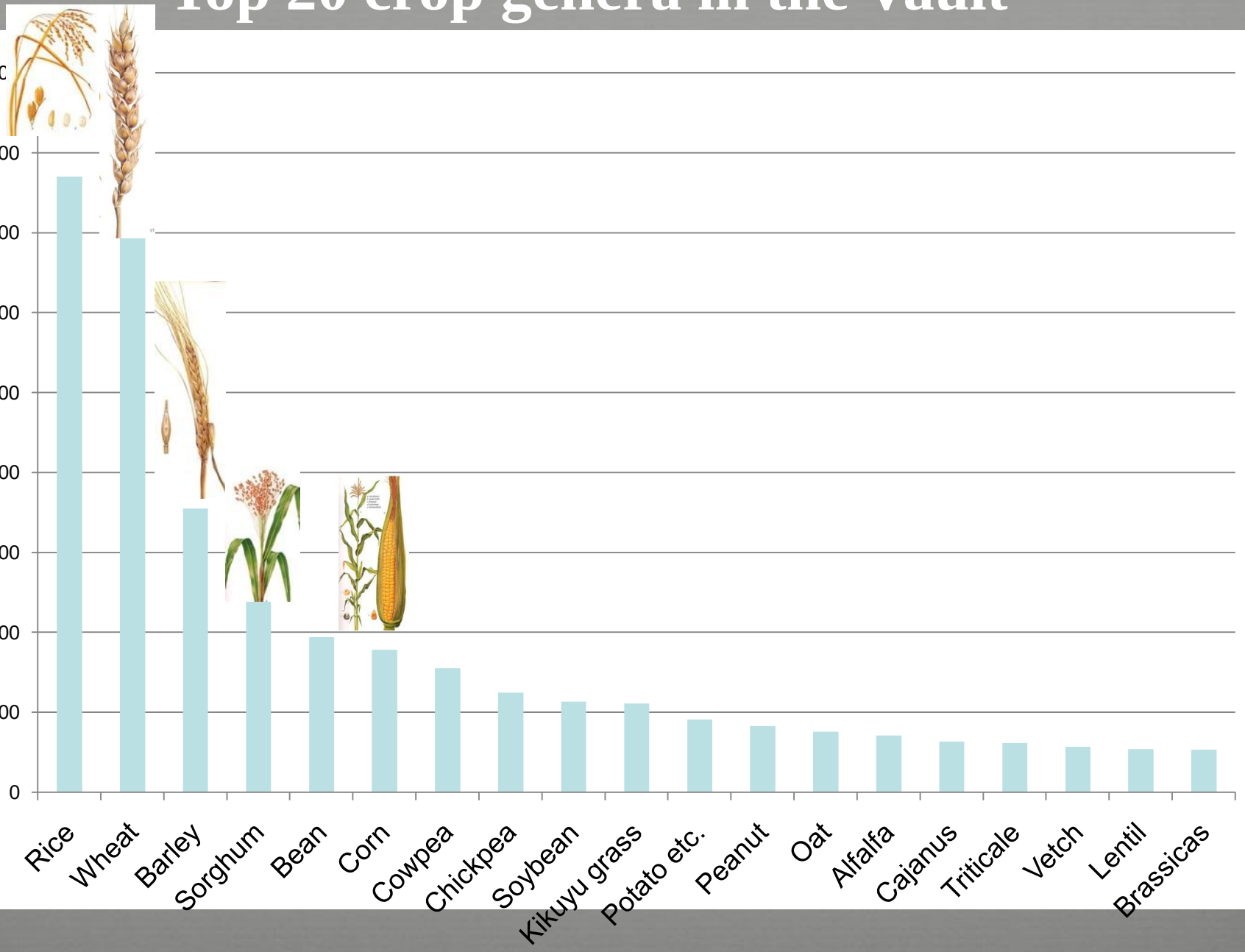


International Agricultural Centers



The proportion and numbers of safety duplicates currently deposited in The Vault at the end of 2015 by different types of gene banks.

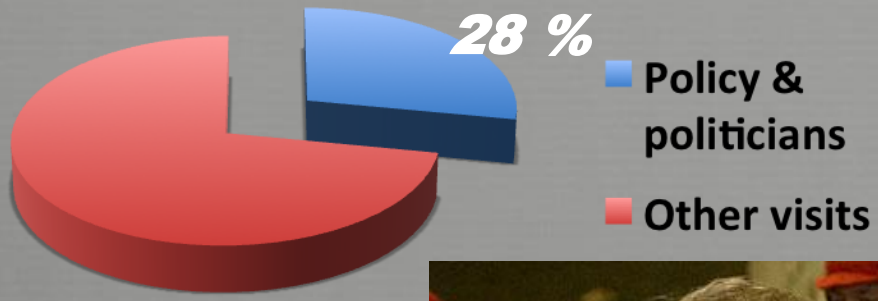
Top 20 crop genera in the Vault



PUBLIC AWARENESS

The Vault gets a large attention and is an "exotic magnet"

Visits: policy makers and politicians



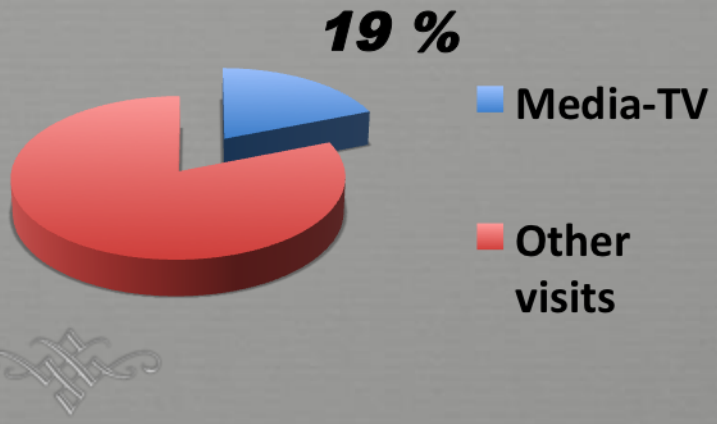
Visits: celebrities

A special visit

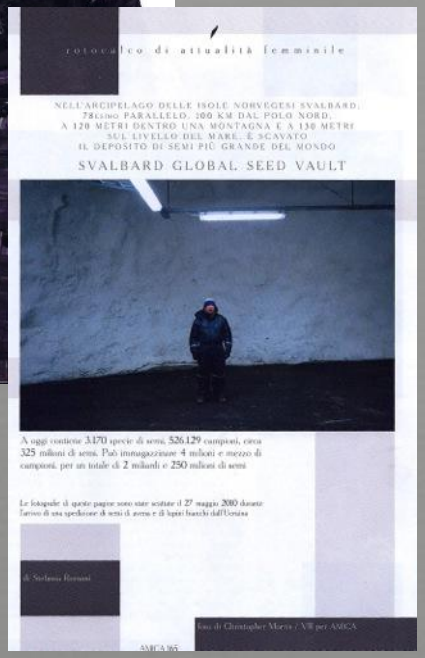
March 13, 2013: HRH The *Princess Maha Chakri Sirindhorn*

The first deposit from Thailand

Visits: Media-TV



Visits: Media-magazines



AMICA

Fashion magazines

18 %

Media-magazine

Other visits

TOPOLINO

comics

What does the future look like?

?

?

Is this our future??

Chemical treatment in Durian

… or this??

THE SEED VAULT IS IMPORTANT FOR GLOBAL FOOD SECRITY!

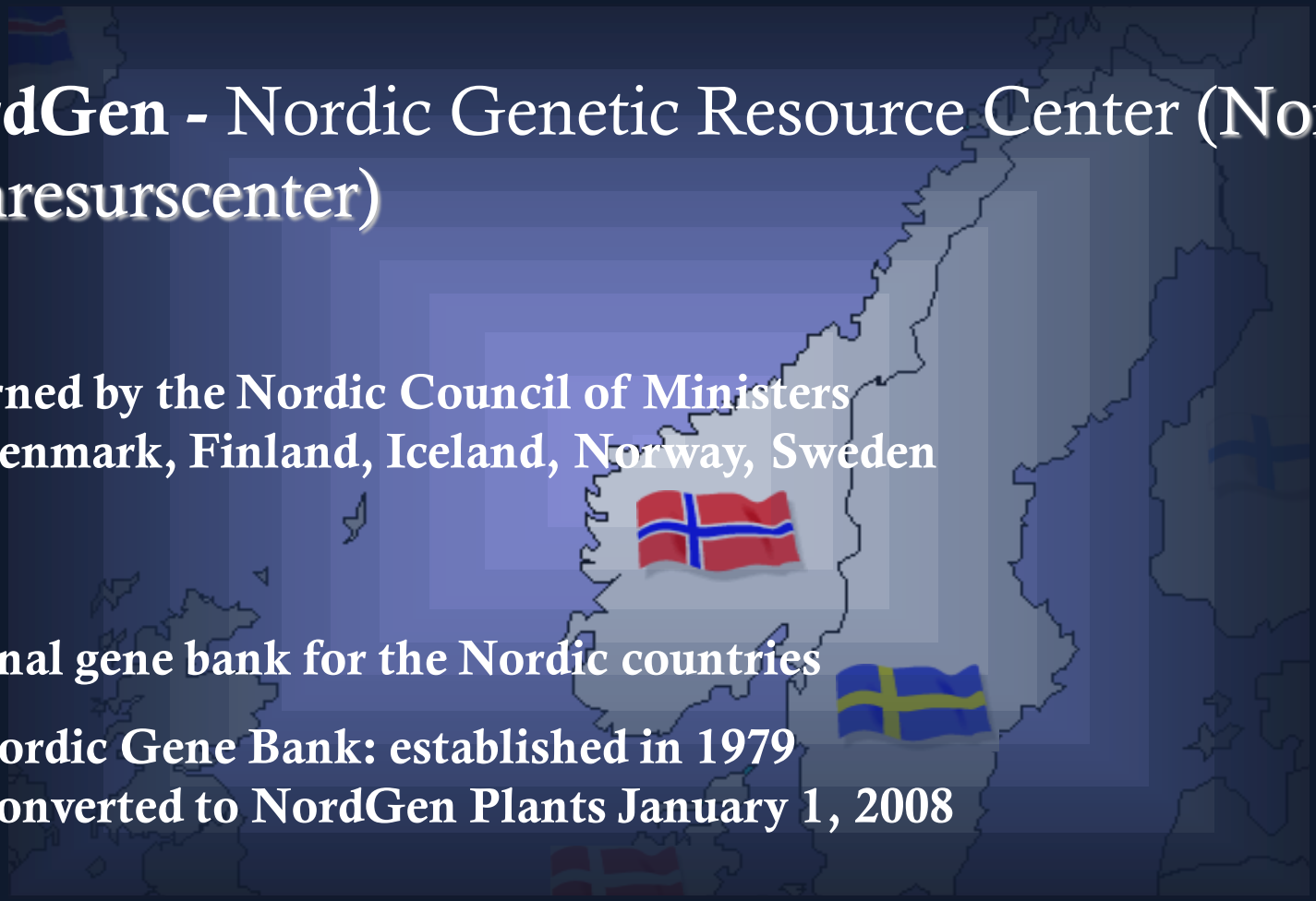
THANK YOU!

The Svalbard Global Seed Vault

Tefre

NordGen

NordGen - Nordic Genetic Resource Center (Nordiskt Genresurscenter)



Governed by the Nordic Council of Ministers
Denmark, Finland, Iceland, Norway, Sweden

Regional gene bank for the Nordic countries

Nordic Gene Bank: established in 1979
Converted to NordGen Plants January 1, 2008

Global policy context

ITPGRFA: “cooperate to promote the development of an efficient and sustainable system of *ex situ* conservation…”

GPA: “develop a rational, efficient, goal oriented, economically efficient and sustainable system of *ex-situ* conservation and use ...”

Större grödor i Frövalvet
(*accessioner/fröprov*)

***Ris** (Oryza)*	**154 060**
***Vete** (Triticum)*	**143 693**
***Korn** (Hordeum)*	**71 683**
***Durra** (Sorghum)*	**48 510**
***Bönor** (Phaseolus)*	**39 289**
***Majs** (Zea)*	**35 651**

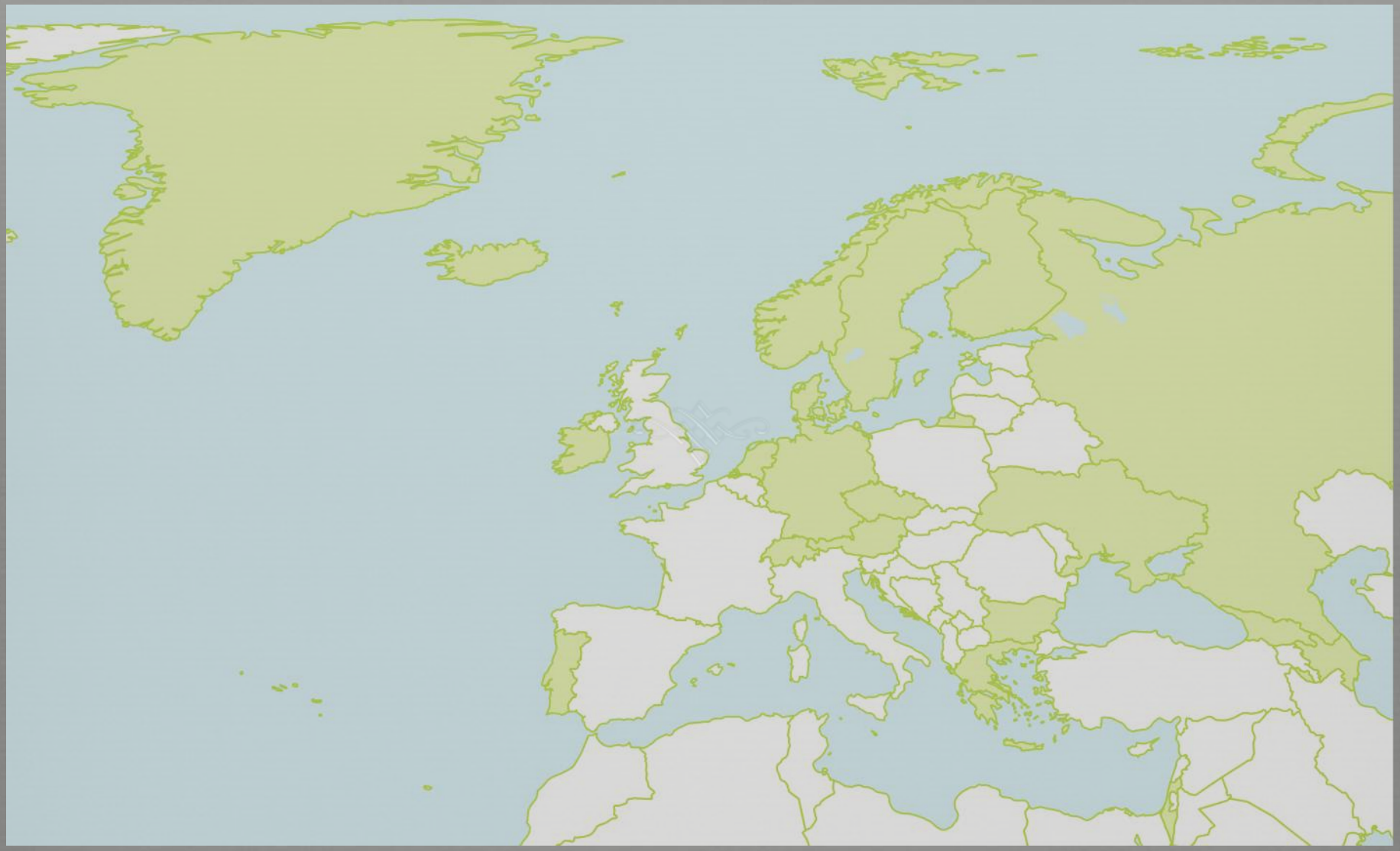
17 sept, 2016

THE VAULT– for future food security

Inside the Vault

Seed boxes from ICARDA

Old and new packings



Green – European countries that have deposited seeds in SGSV

Strukturen

- Valvet ligger 120 m inne i berget
- 130 m ovanför havsytan; ovanför ”worst case scenario” för klimatförändringar
- Geologiskt (och politiskt?) stabilt område
- Temperatur i valvet -18˚ C
- Permafrosten garanterar -4 ˚ C vid tekniska problem
- Övervakning och kontroll med gas-, temperatur- och rörelsedetektorer

NordGen

Forage crops

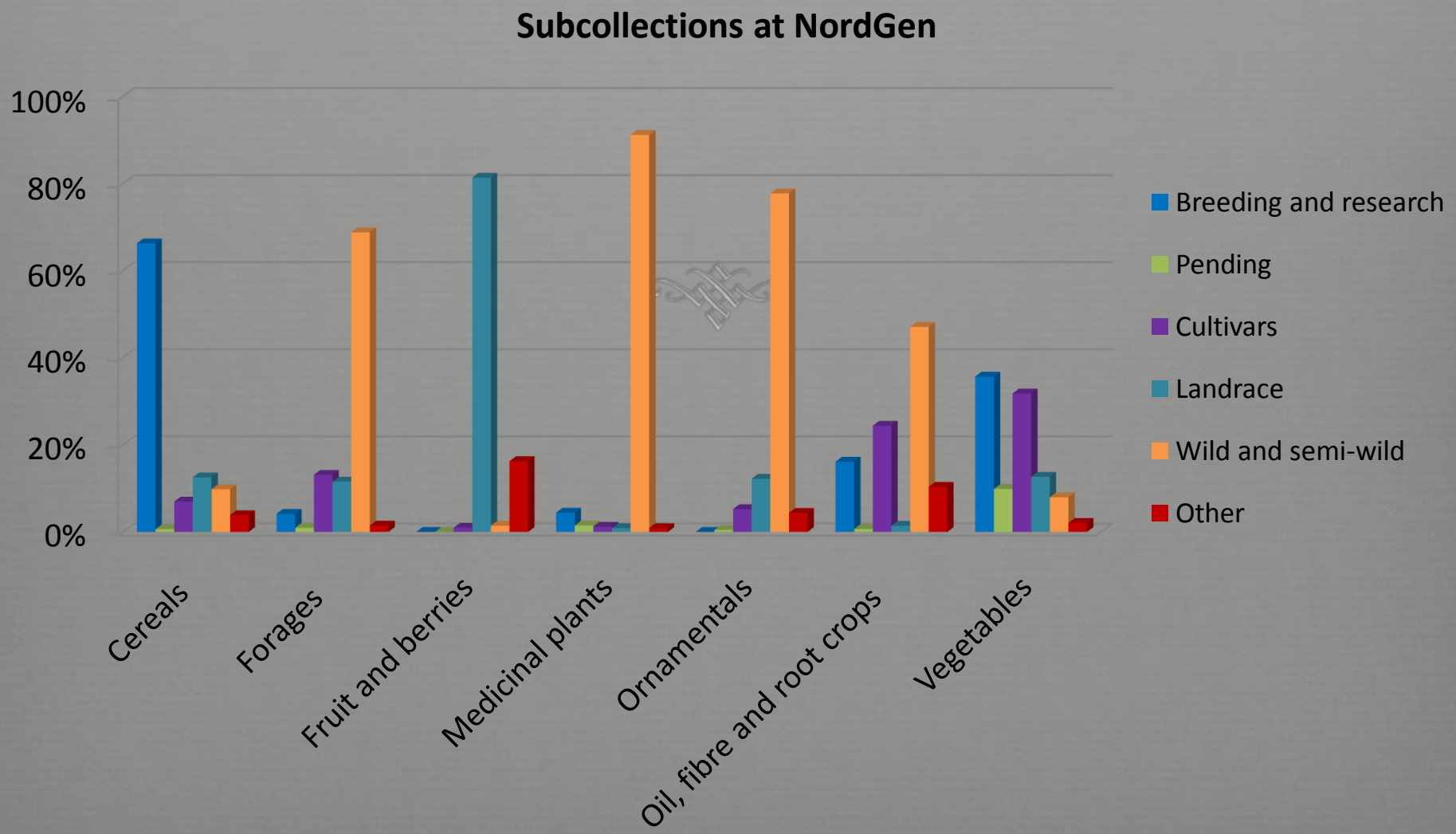
Genus	No. of acc.
Trifolium	860
Phleum	830
Festuca	800
Poa	560
Agrostis	350

Industrial crops

Genus	No. of acc.
Barbarea	570
Linum	365
Brassica	260
Beta	120
Papaver	92

NordGen

Composition of the sub-collections



In progress

1) Jahoors collection (~4000 lines, 2014-2017)

1090 wild barley
500 barley landraces (Eritrea)
489 wheat landraces (Eritrea)
Ralla x XX85 (synthetic wheat)
Advanced resistance lines
Root hair mutant (cv. Gahoonia)
Old Nordic cultivars
Cytogenetic stocks (addition lines, etc)

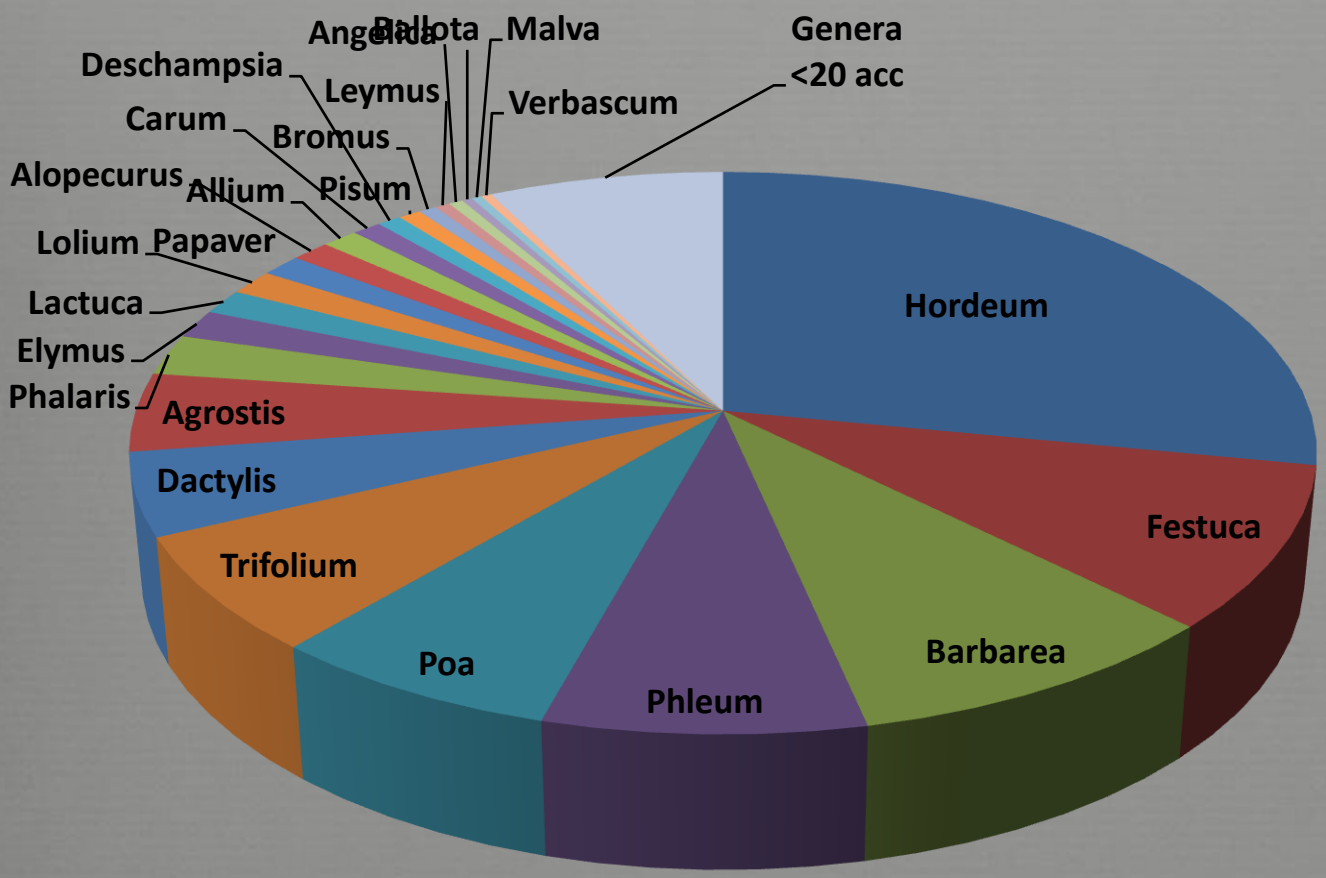
2) RvB Triticea collection (2014-2016)

Documentation and selection (RvB), and regeneration




NordGen

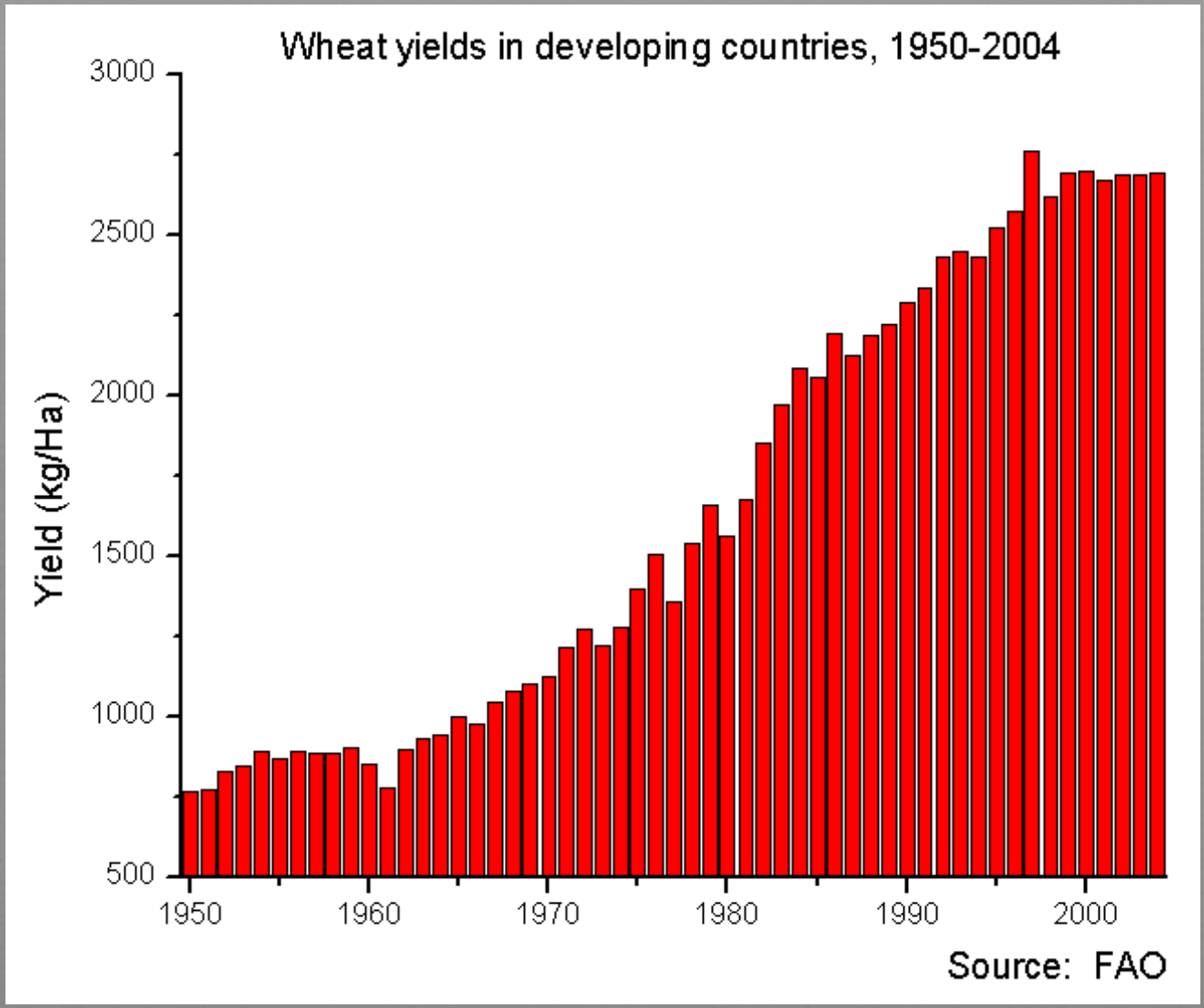
Wild accessions at NordGen



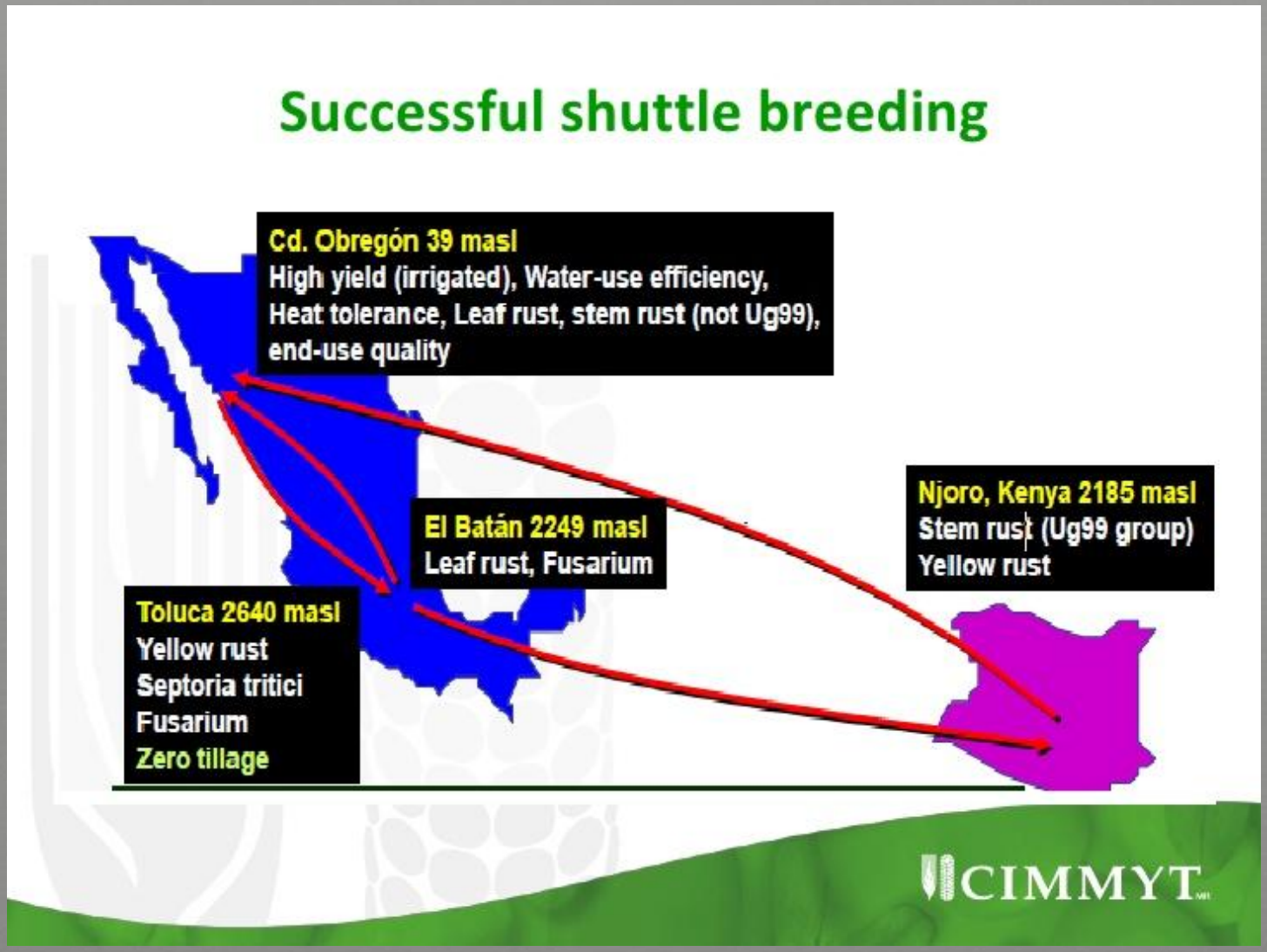
The man behind ”THE GREEN REVOLUTION”

Norman Borlaug

The success has been evident – wheat yield increased over years



The genius behind ”THE GREEN REVOLUTION”



Cereal collection (ACC/PEN)

Type	Accesions
Cultivar	1.731
Landrace	2.508
Breeding / Research	14.926
Wild	2.159

Genus	Accesions
Hordeum	16.531
Triticum	1.979
Avena	531
Secale	328
Other	347
	19.716

In total 121 different species

NordGen

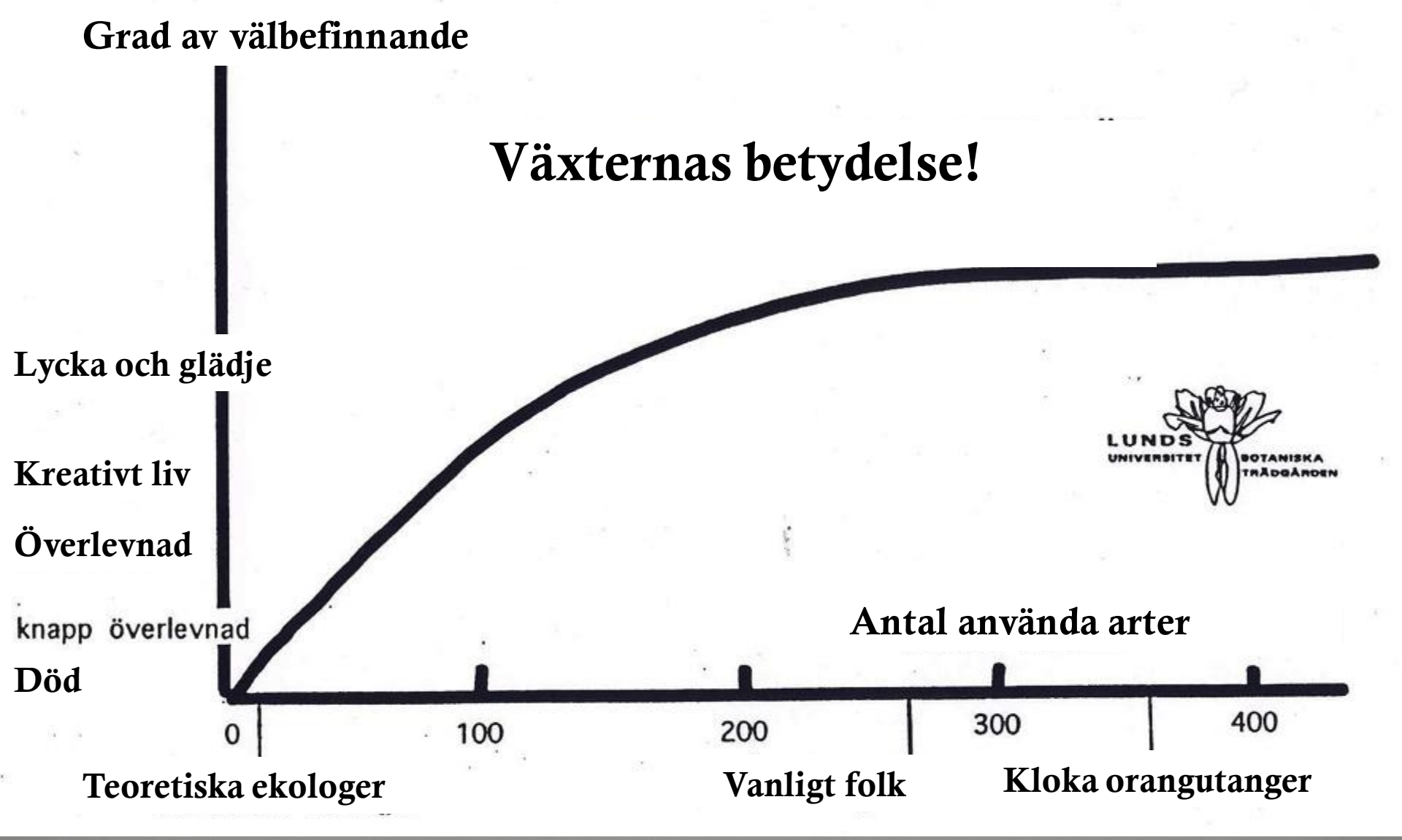
Svalbard Global Seed Vault

- No genebank! An international security storage
- No distribution of seeds, unless request from the owner country
- Norway owner
- Administered by 3 parties – Norwegian government, Global Crop Diversity Trust, and NordGen.

Other cereal genetic stock collections

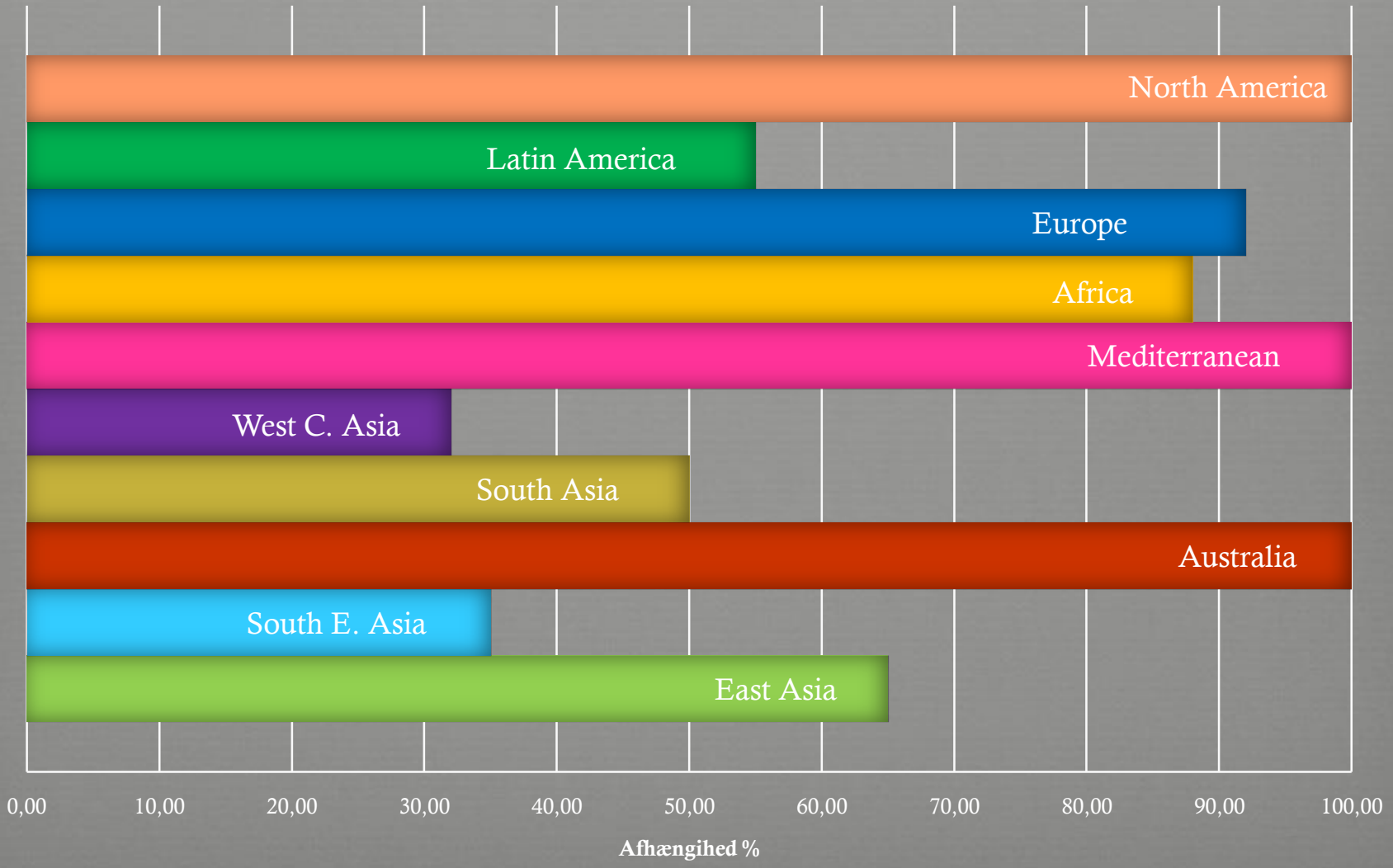
No. of acc.	*Types of Genetic Stocks*
412	James Mac Key near isogenic lines (wheat)
5	Test assortment for resistance to *Heterodera avenae* and related species (wheat)
208	James Mac Key near isogenic lines (NIL) (oat)
131	Inbred rye collection ’Stål’

Växternas betydelse!



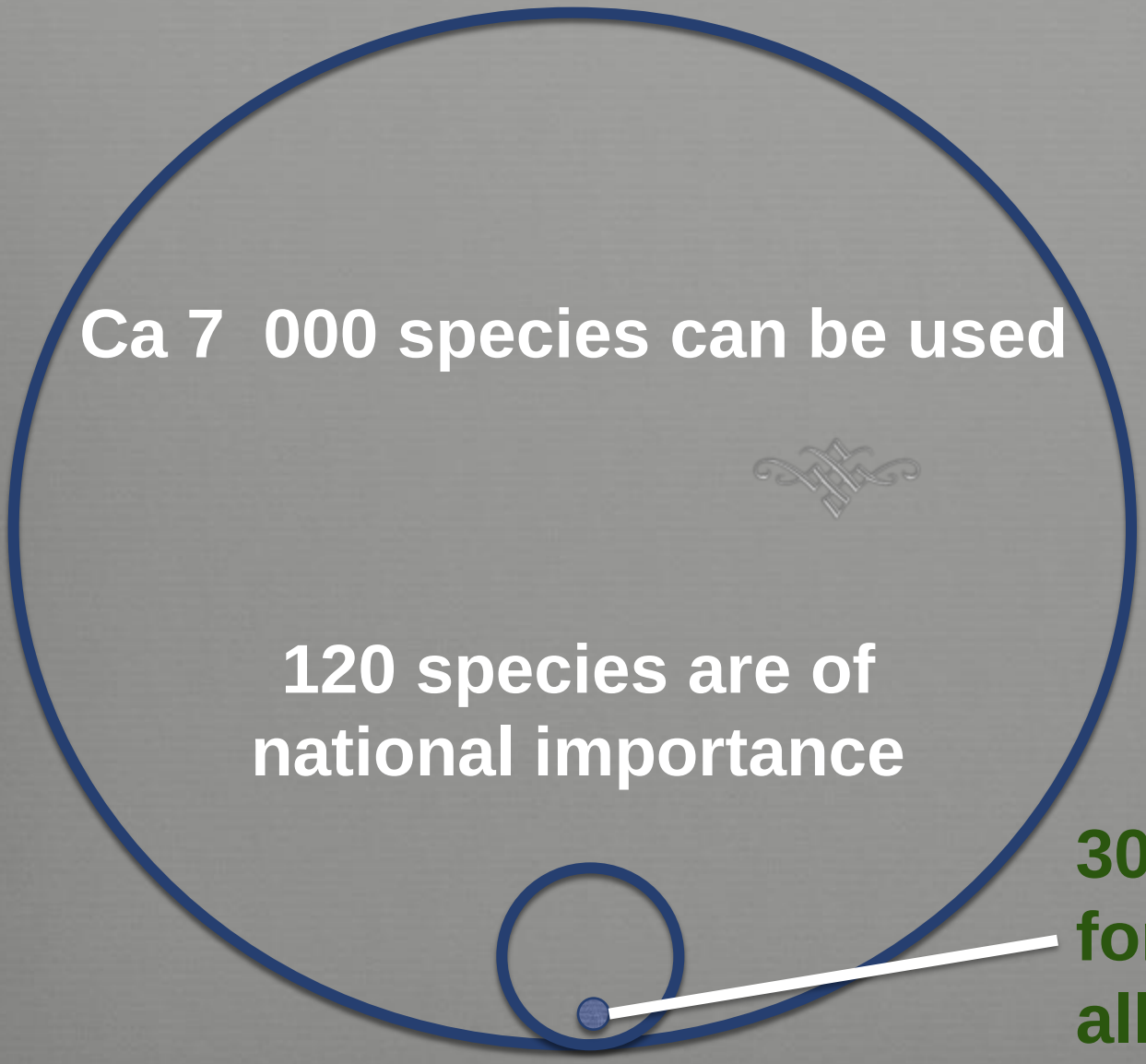
MATPRODUKTION BASERAT PÅ ARTER MED URSPRUNG I ANDRA OMRÅDEN

BEROENDE AV IMPORTERADE GENRESURSER



How many species do we use?

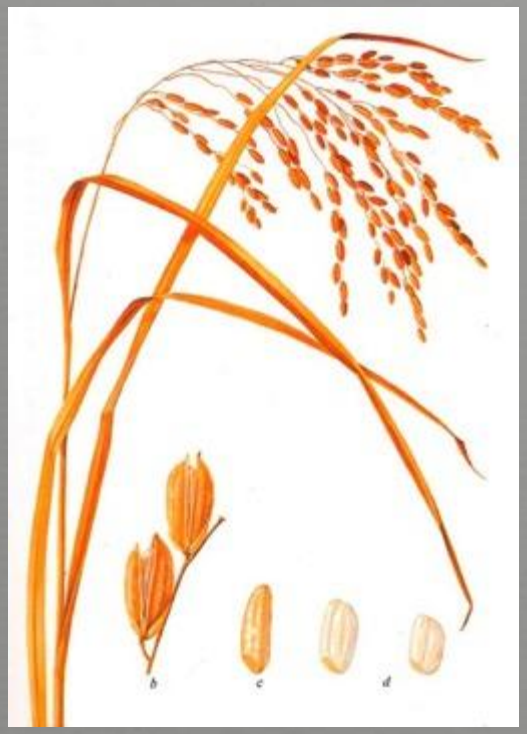
Ca 400 000 species of higher plants



30 species stand for 90 % of all calories

Three species stand for 60 % av all calorie uptake globally!!

Rice



Maize

Wheat

A hugh vulnerability!!

A vault for a remote future or a vault for current operations of the PGR world?

- «An insurance, hopefully it will never be used»
- «The Doomsday Vault»
- «A part of a global system for the Conservation and Use of PGR»

- The first request for withdrawal of seeds came from ICAR September 2015

- Cay Fowler 2008:
  - If we built the Svalbard Global Seed Vault ten years ago, we had used it several times already, e.g. in Afghanistan or in Ira


Plants »


Farm Animals »


Forest »

NordGen

- Cultivated plants & wild relatives
  - Agricultural, horticultural, landscape & ornamental plants
  - Seed gene bank
  - Clonal material in collaboration with national programs
  - Nordic Networks

- Farm Animals
  - Collaborative
  - *In Situ*, in breeding programs

- Forest trees
  - Collaborative
  - *In Situ*, in forest reserves