Seed longevity and genetic variation of orthodox seed in crop GeneBanks

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PGR maintenance at IPK

Seed cold storage
(~144,000 accessions)

Field genebank
(2,650 accessions)

Slow-growth storage
(3,150 accessions)

Cryo (2,400 accessions)

Photos: S. Rey (2016), L. Maine (2016), M. Nagel (2019)

Structure

1. Historic seed storage experiments

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2. Variation in seed longevity

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3. Challenges of long-storage experiments

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4. Genetic variation in seed longevity

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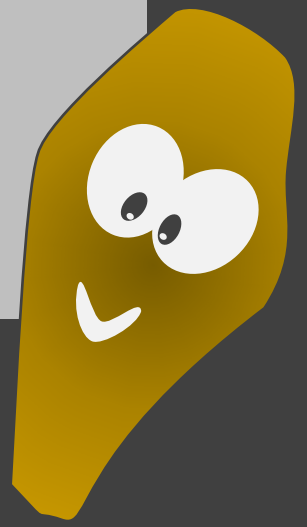
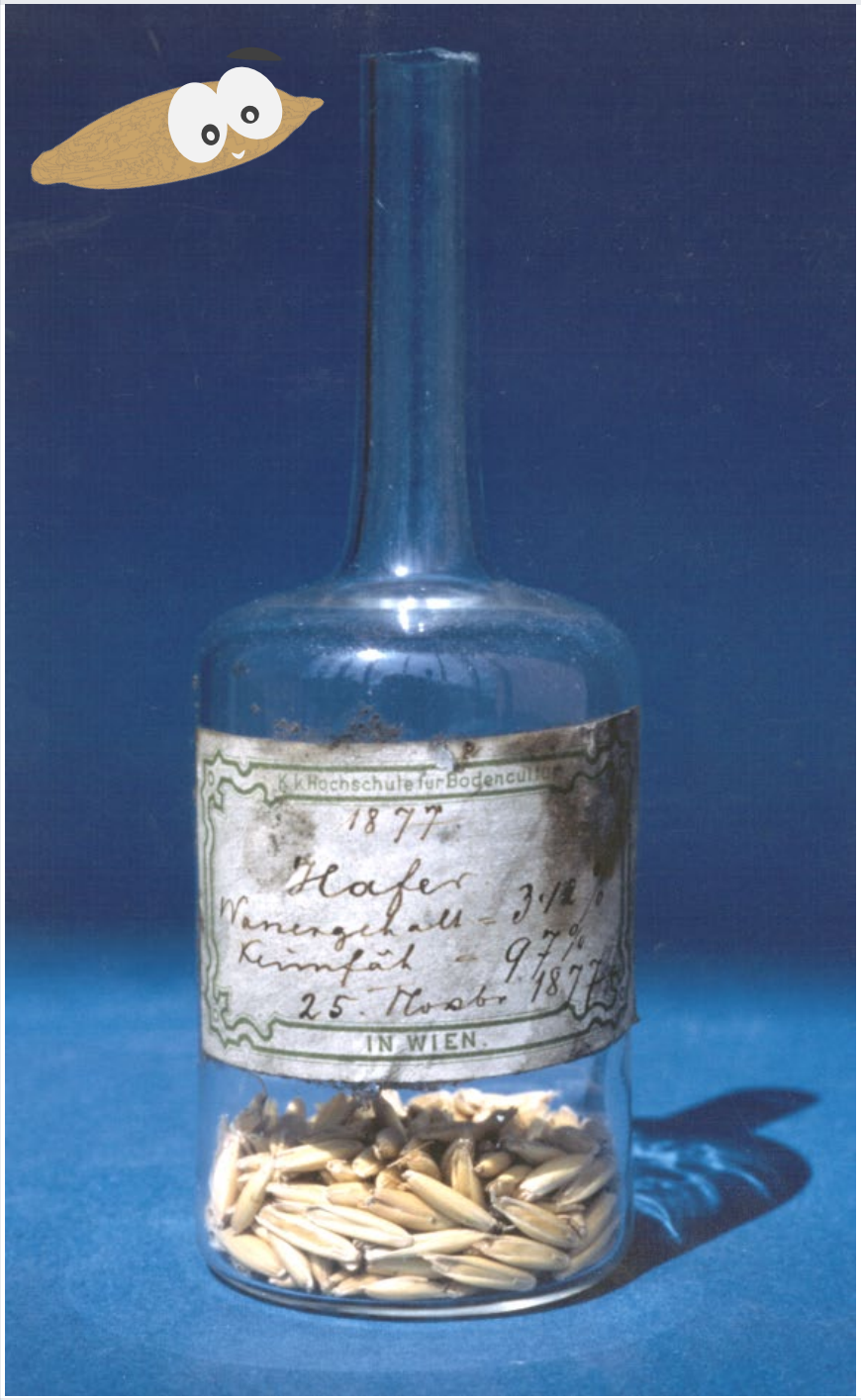
1. Historic seed storage experiments





Source: Steiner, A.M., and Ruckenbauer, P. (1995). Seed Science Research 5, 195-199. https://doi.org/10.1017/S0960258500002853
Picture: Prof. Michael Kruse

Vienna samples

- Friedrich Haberlandt (1826-78), BoKu University Vienna
- Storage experiment started on 25th November 1877
- Initial germination of oat; 97% and 3.14% water content
- Stored for 110 years at about 15 °C
- Final germination of oat was 81%

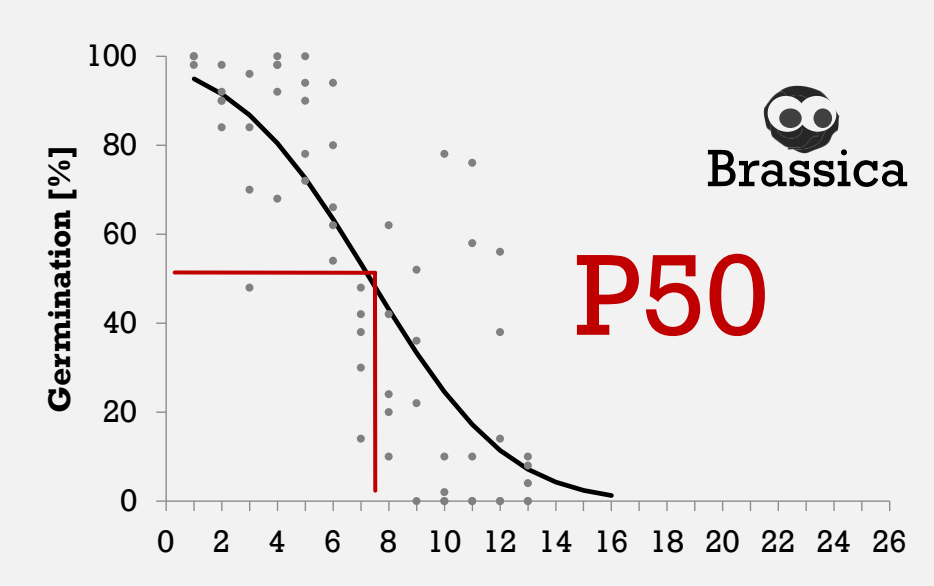
Nicolai I. Vavilov (1887 – 1943)

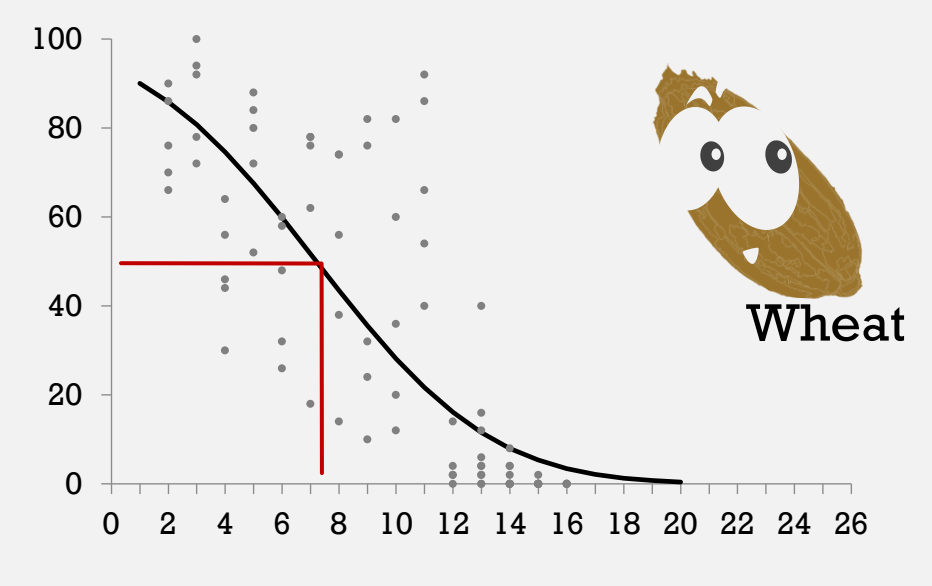
Vavilov, N.I. (1926). Bulletin of Applied Botany, of Genetics and Plant Breeding 16, 1-248.

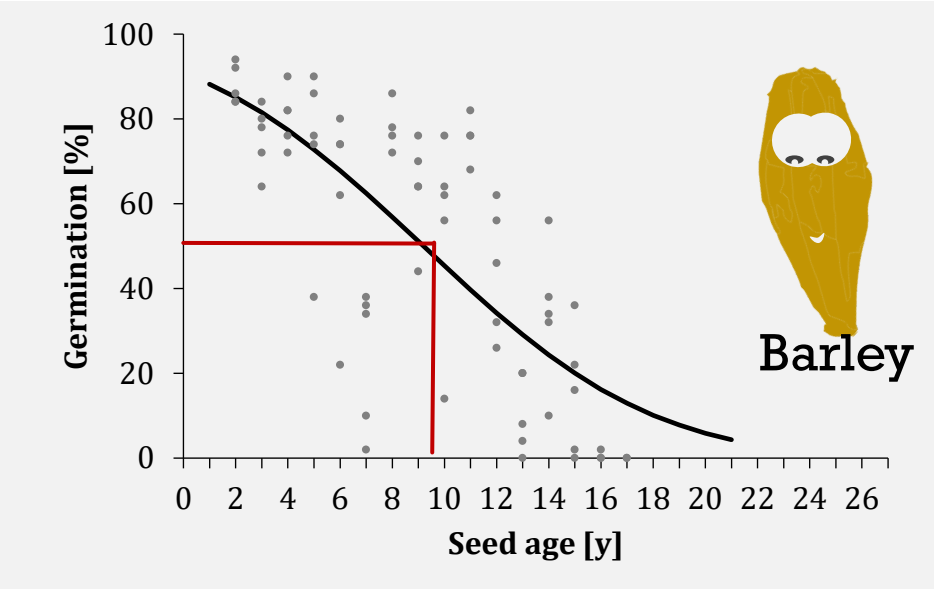
2. Variation in seed longevity

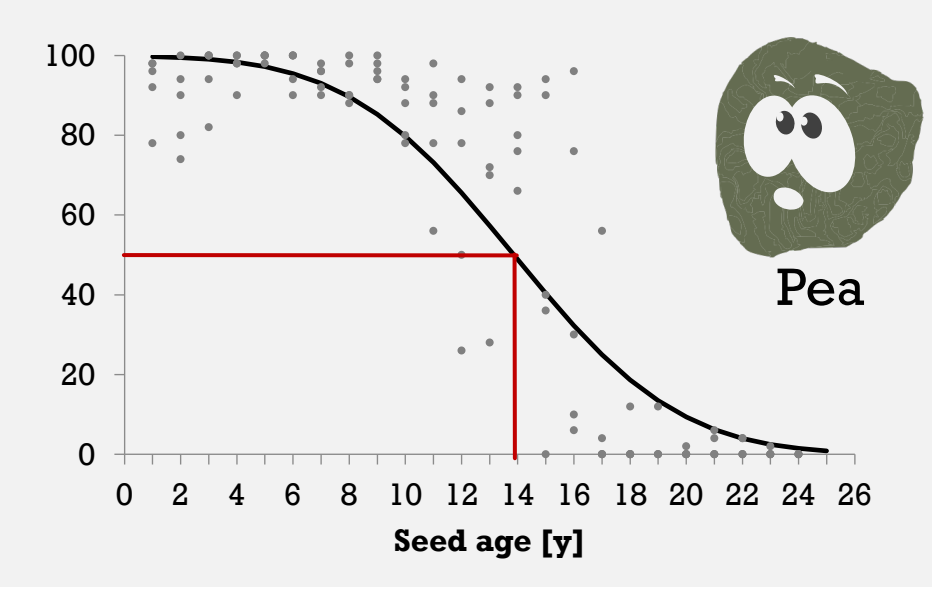
Seed longevity is species‘ dependent

P50 = half-viability period



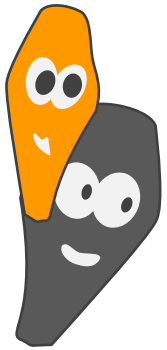


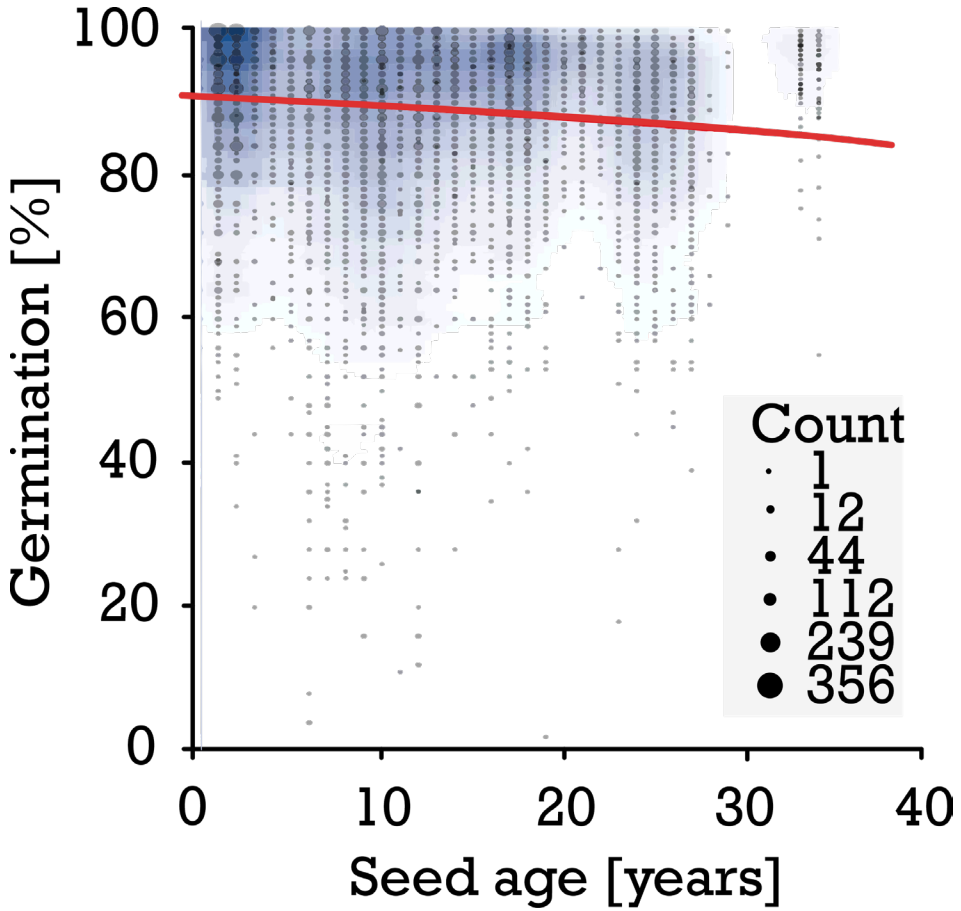




Nagel & Börner (2010)
https://doi.org/10.1017/S0960258509990213

Seed longevity varies between genotypes





Nagel & Schulze-Brüning (2018), unpublished data

Photo: Rey (2010)

P50

Brassica = 85.3 y

Wheat = 115.5 y

Pea = 227.6 y

N =12,500 tests

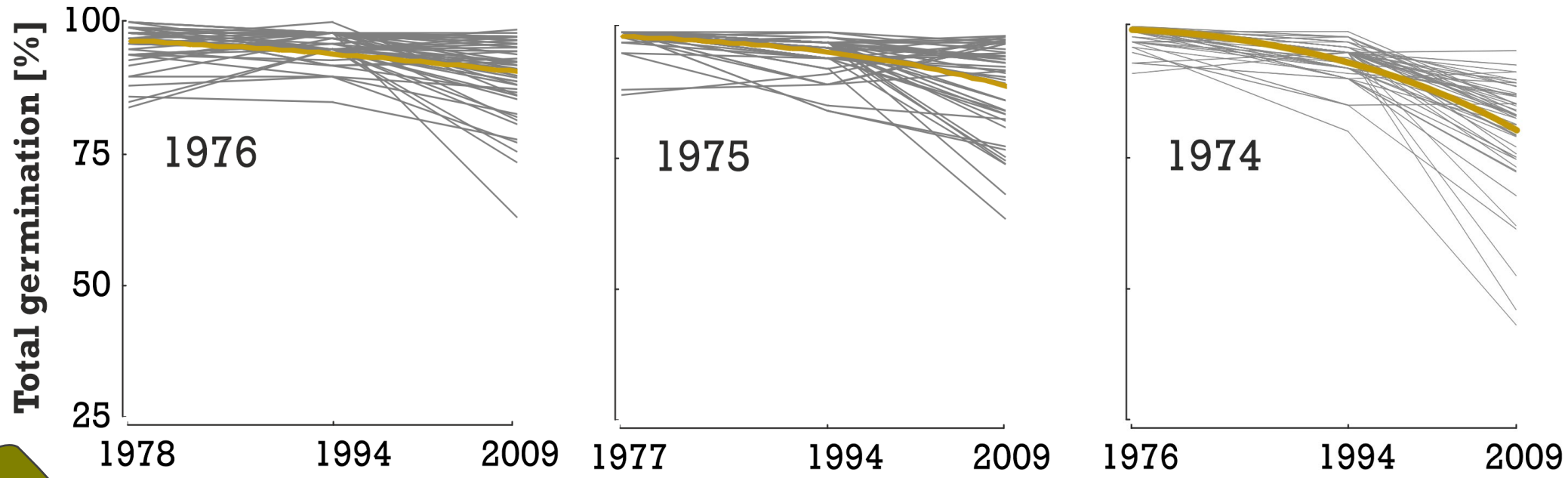
P50 = 155.6 y

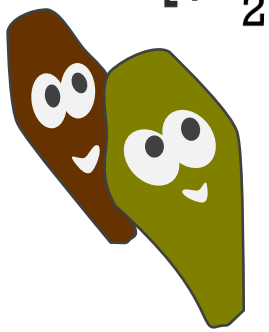
Seed longevity depends on growth environment

P50 = 115.5±0.01

P50 = 70.8±0.01 y

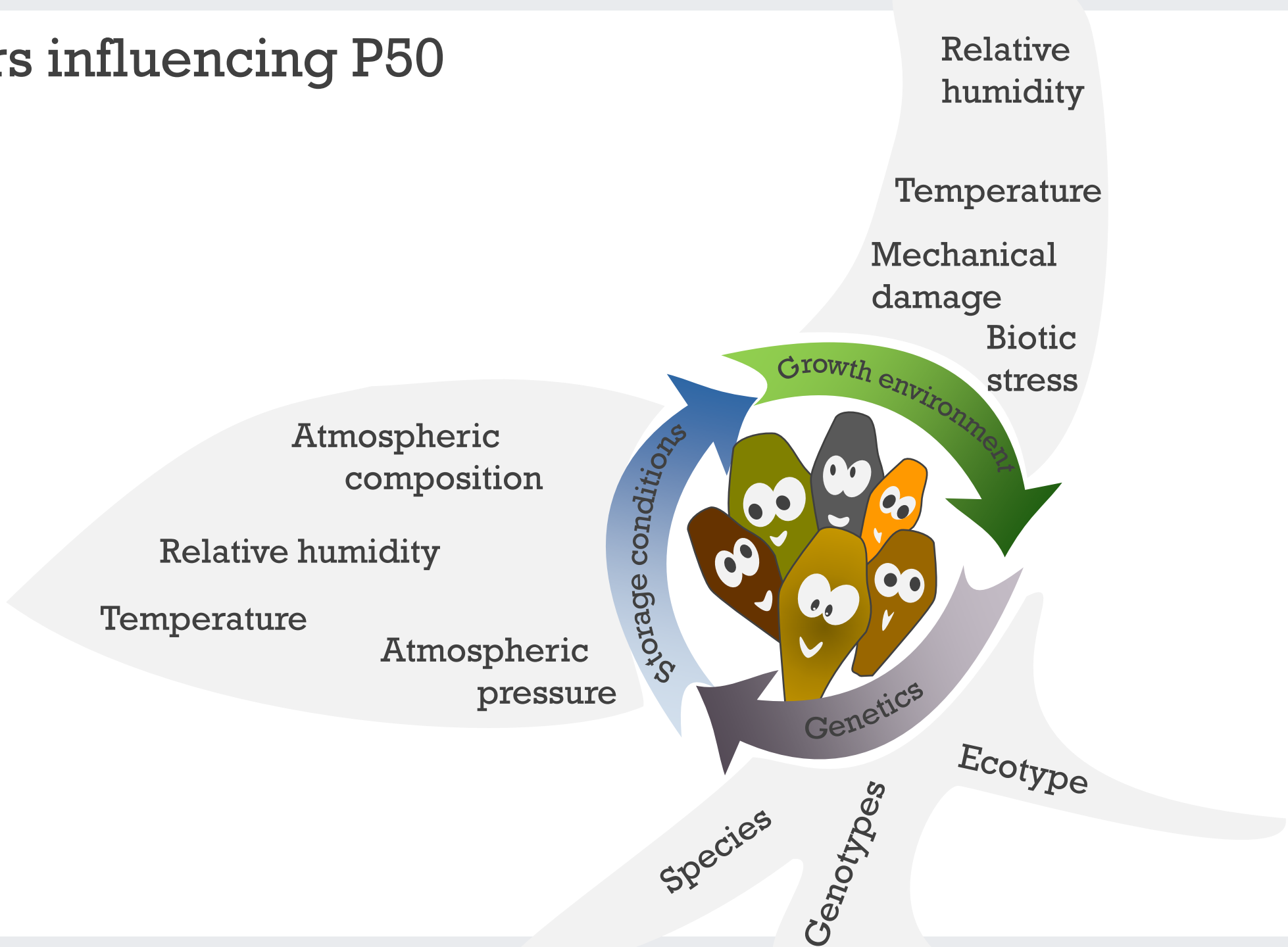
P50 = 52.6±0.01 y



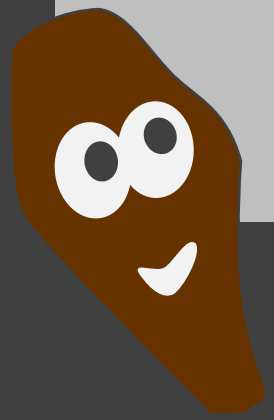


Nagel (2011) Cuvillier Verlag Göttingen, IBAN 978-3-869558714

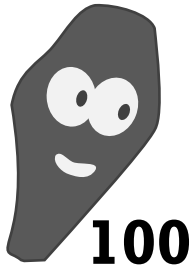
Factors influencing P50



3. Challenges of long-storage experiments



Storage conditions



100%

Artificial ageing
(30°C, 60% RH)

500d

Artificial ageing
(45°C, 100% RH)

3d

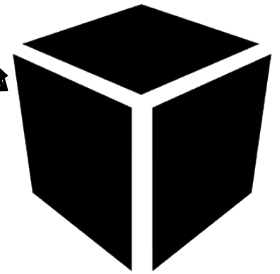
Long-term ambient storage
(20°C, 50% RH)

9y

Long-term cold storage
(-18°C, 13% RH)

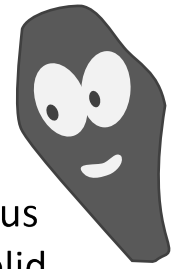
155 y

50%



Nagel (2022) Cuvillier Verlag Göttingen, IBAN 978-3-736975576

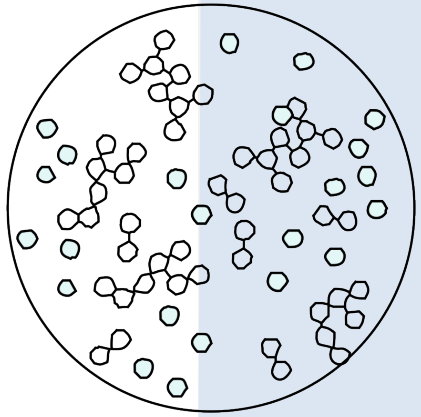
Storage at the glassy state



Liquid state

V IV III II I

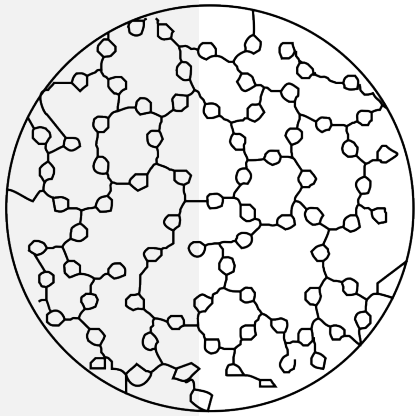
Amorphous (glassy) solid



Cells and organelles shrink

Increasing viscosity of cytoplasm

Increasing conc of reactant molecules



Solution
> 0.7 g H_2O g^{-1} DW
> 99% RH
> -1.5 MPa

Syrup or Rubber
> 0.2 g H_2O g^{-1} DW
> 90% RH
> -15 MPa

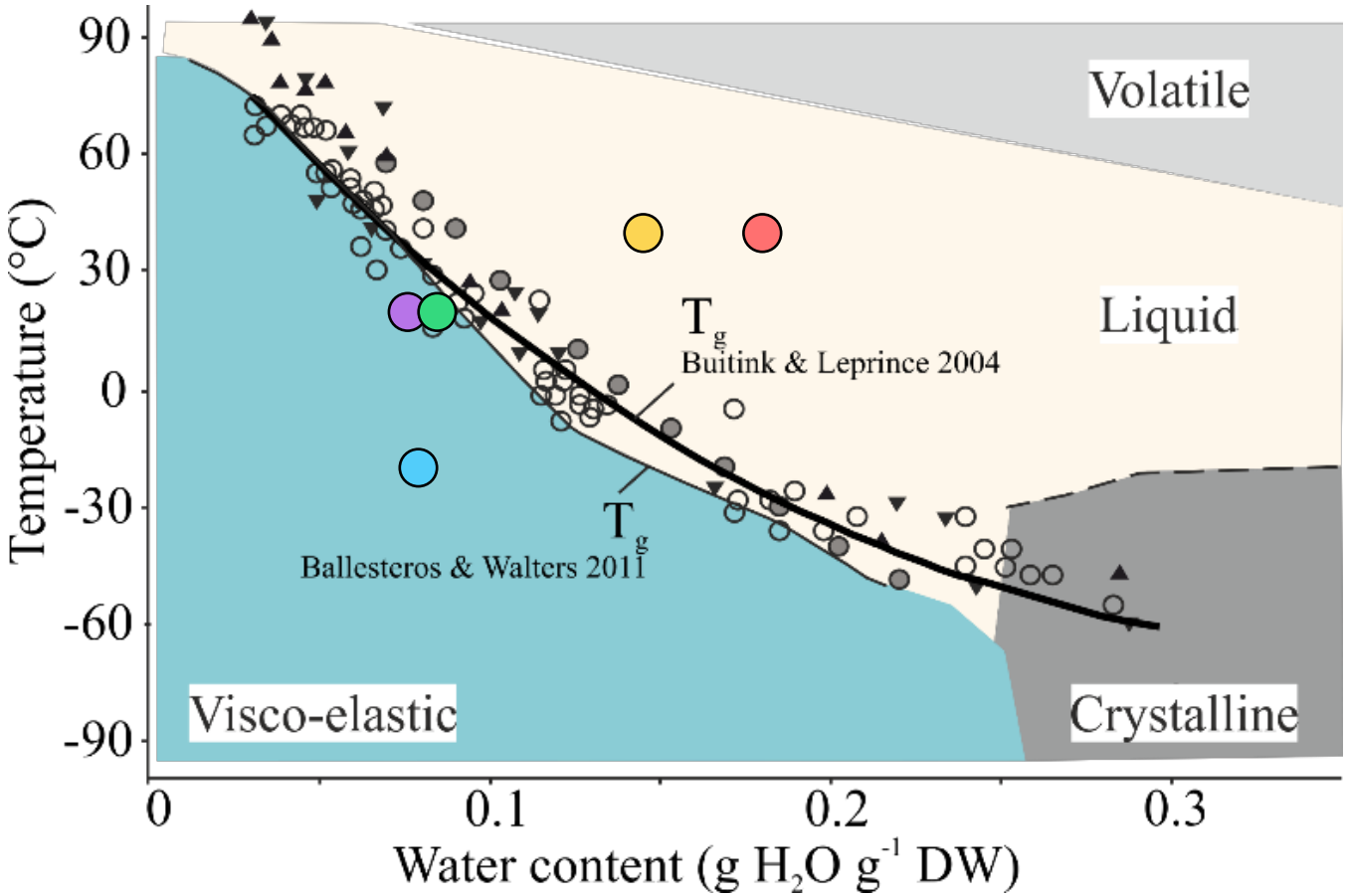
Glass
~ 0.15 g H_2O g^{-1} DW
~ 50% RH
~ -100 MPa

Porous glass
< 0.05 g H_2O g^{-1} DW
< 10% RH
< -200 MPa

Bacteria growth
Yeast growth
Enzymatic activity
Non-enzymatic browning
Lipid oxidation

Walters C. 2015. Planta. Aug;242:397-406, https://doi.org/10.1007/s00425-015-2312-6

Storage at different states



- Freshly harvested (FH, 9% MC, 20°C)
- Ambient storage (AS, 9% MC, 20°C)
- Cold storage (CS, 9% MC, 0°C)
- CD at 14% MC, 44°C
- CD at 18% MC, 44°C

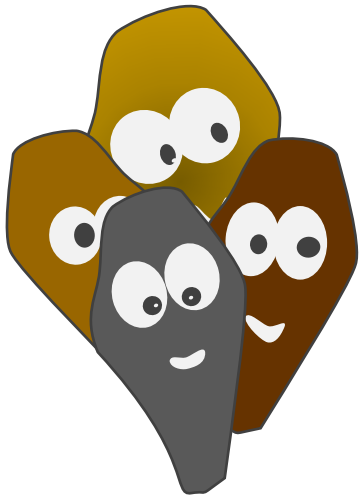
4. Genetic variation in seed longevity

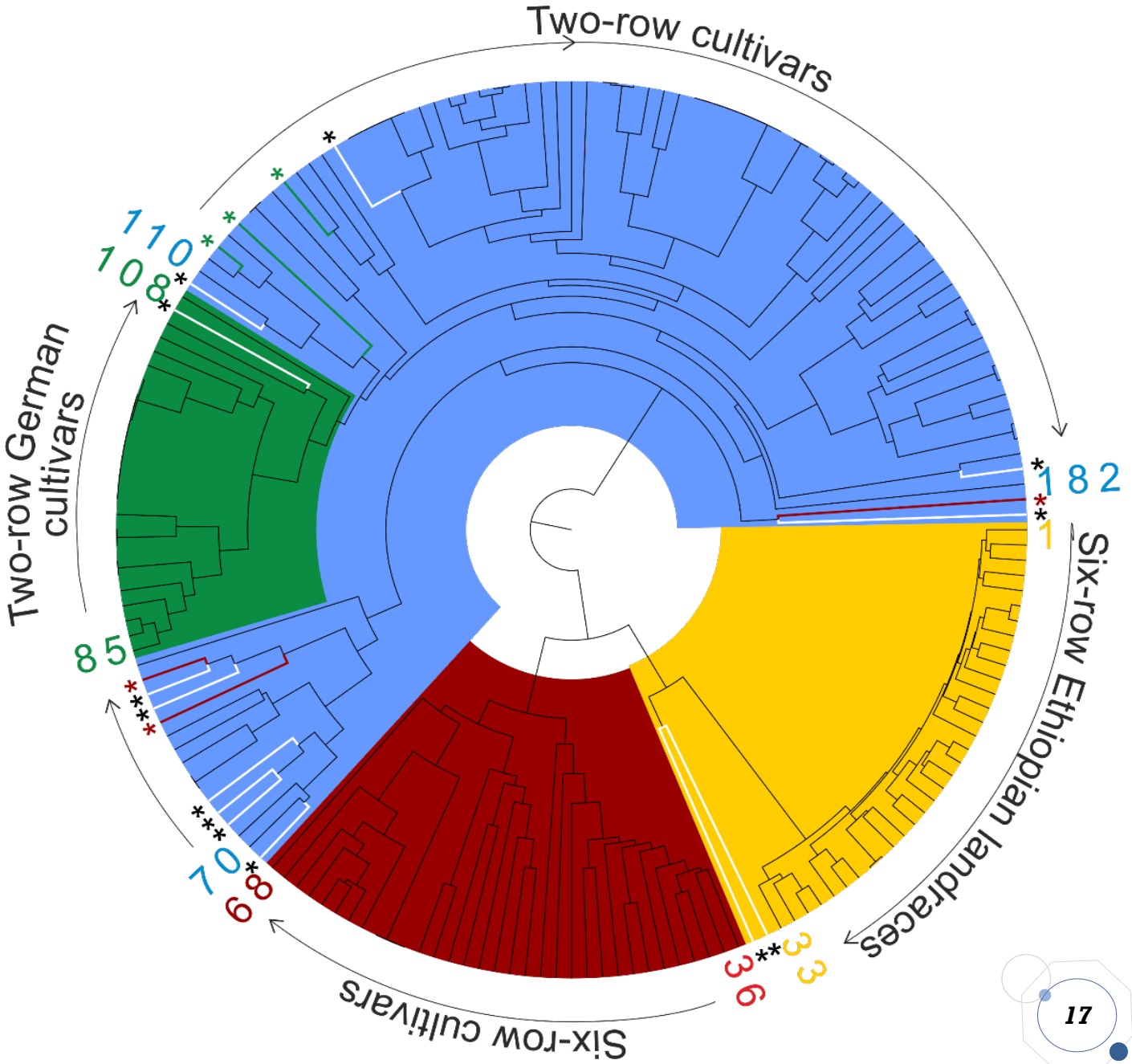
Barley ‚EcoSeed' Panel

Illumina HD 9K chip

7,864 used (MAF < 10%)

4,343 mapped marker





Nagel et al. (2019) Plant Cell and Environment, 42, 1318-1827, https://doi.org/10.1111/pce.13483

Photo: Rey (2010)

40 years of cold storage

184 spring barley genotypes harvested 1974 and tested 2014

LSD5%=12.8%

- Best Linear Unbiased Estimators (BLUEs)
- Total germination (%)
- Normal seedlings (%)

Photo: Rey (2010)

GWAS after 40 years cold storage

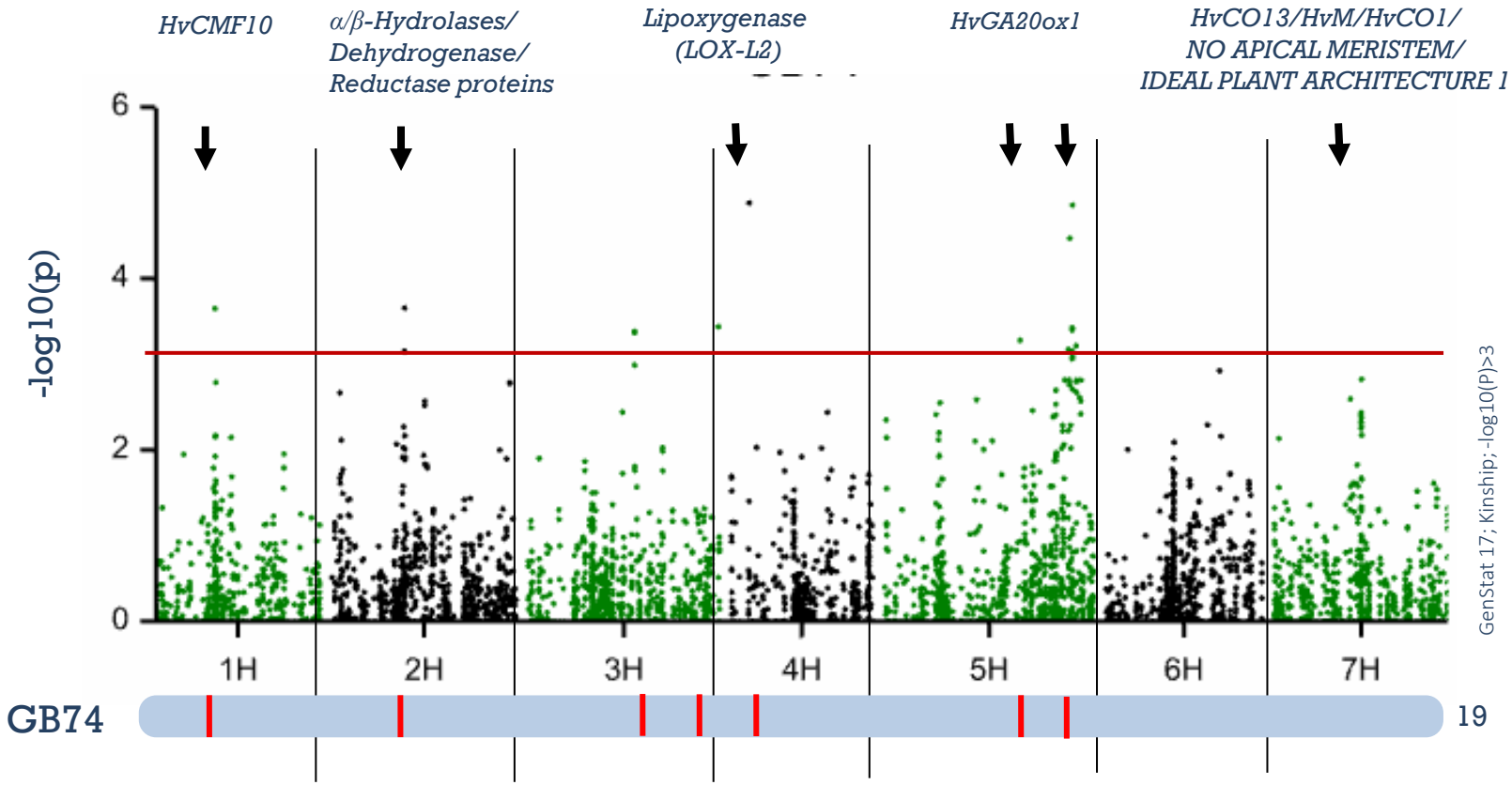
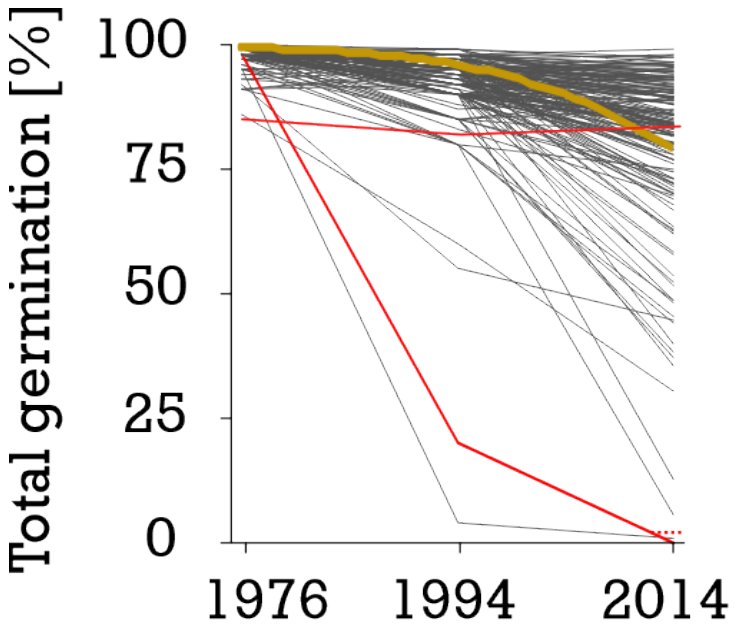
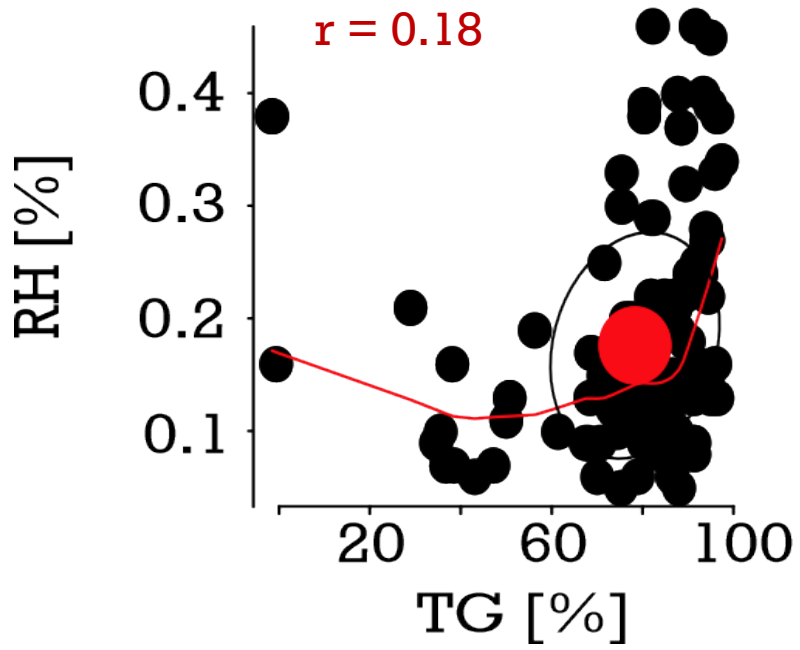


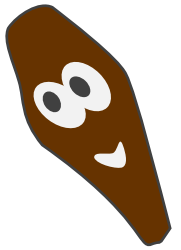
Photo: Rey (2010)

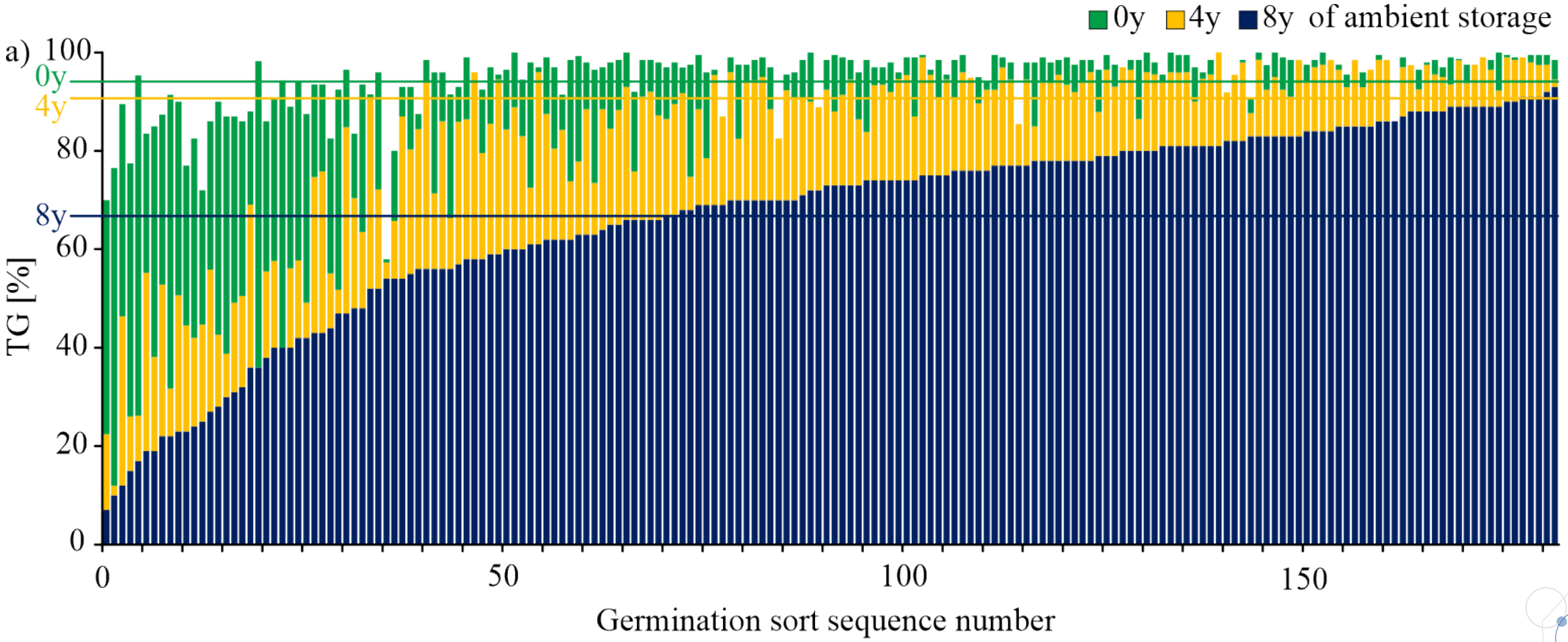
P50 is dependent on the genotypes





GWAS after 8 years ambient storage





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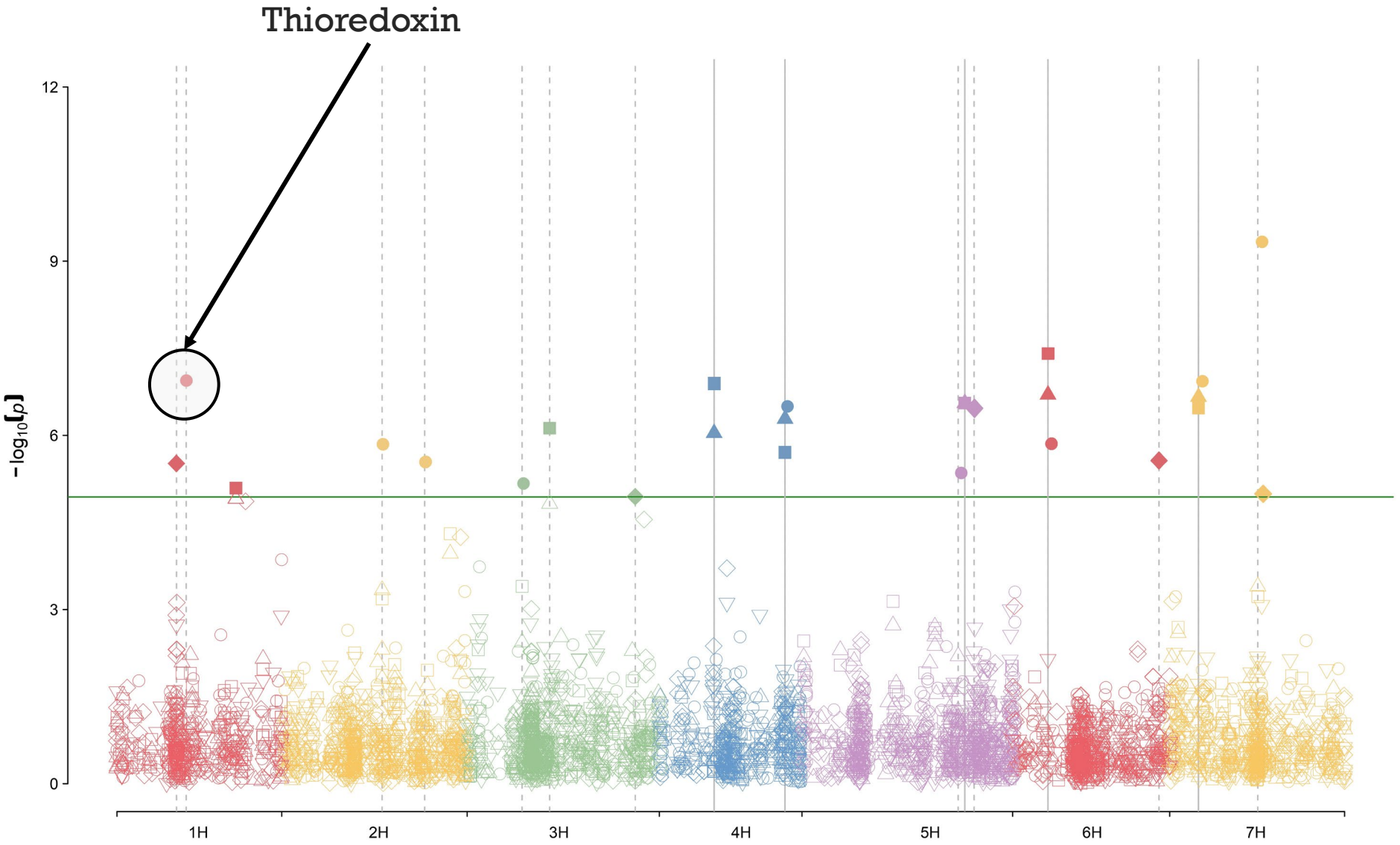
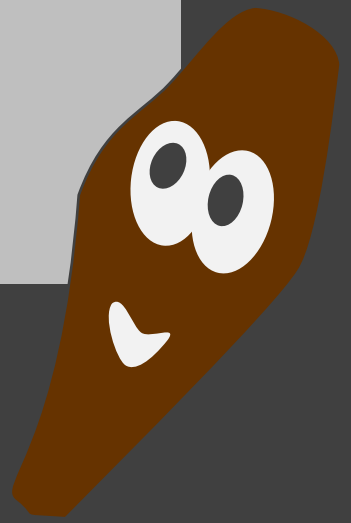


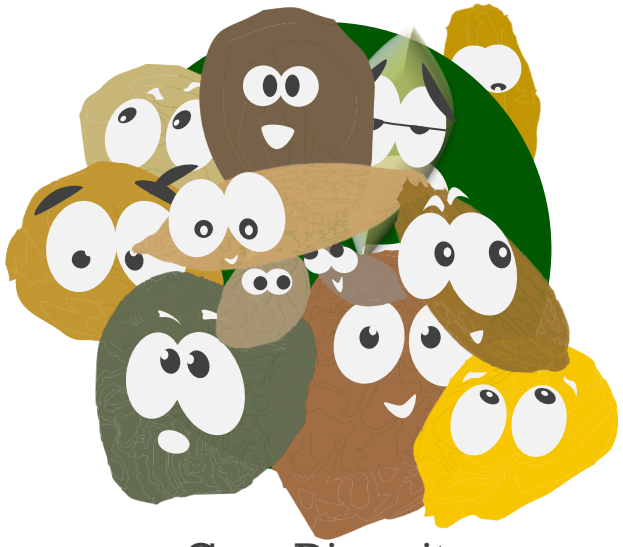
5. Outlook and Conclusions



National Institute for Agrarian and Veterinary Research

INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

Excurs: Advantages of the Svalbard Experiment



Crop Diversity

Years of Productions
= Environments

5

Genotypes per Species
= Diversity

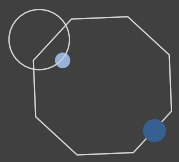
Passport Data &
Conditions of mulitplications

Cryostorage
at IPK

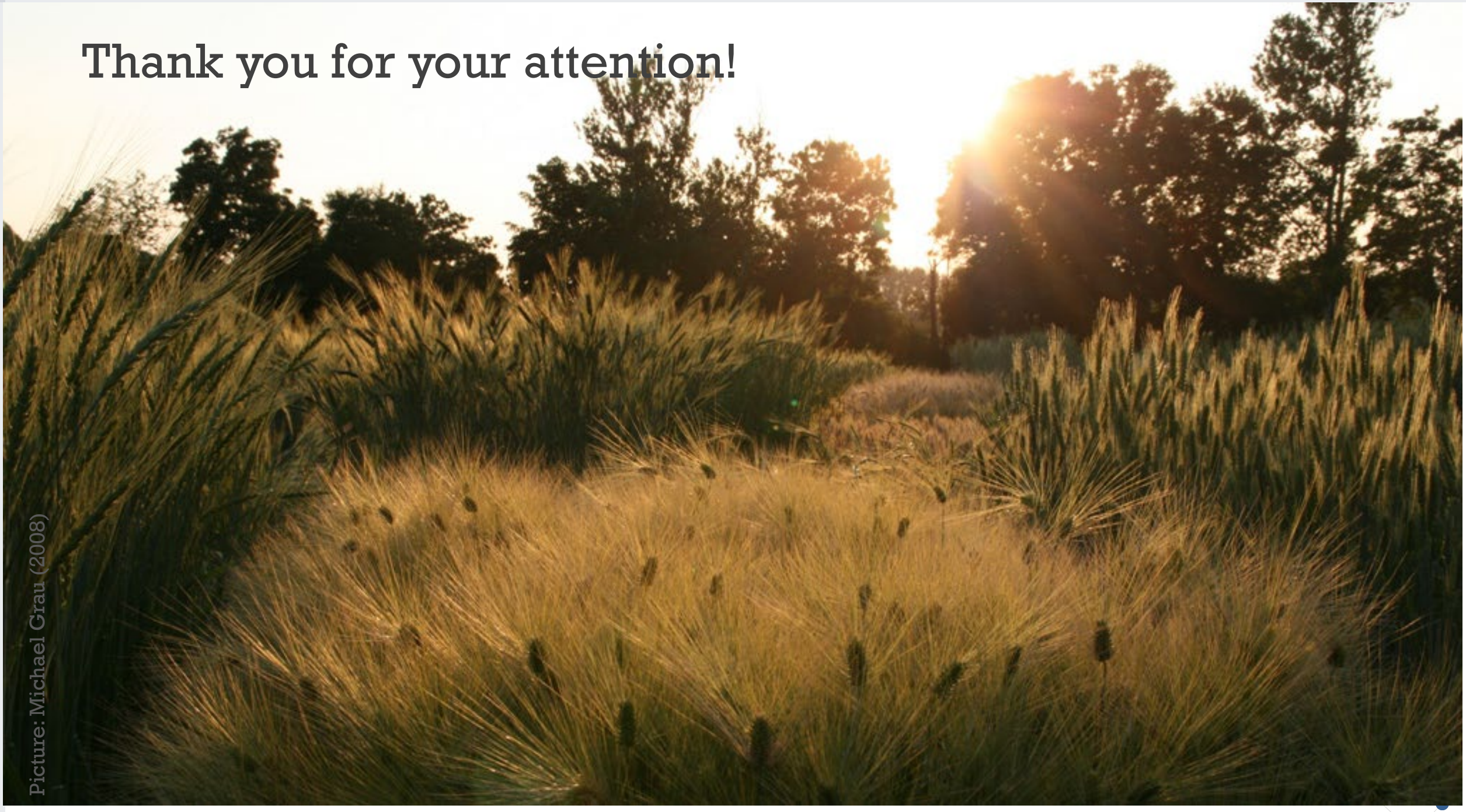
Svalbard Storage
Frequent Germination Tests

Conclusions

- High seed quality and adequate testing methods will be still required in the next 100 years
- More information about the genetic background of seed longevity will be available in future
- This can be used for optimization of storage and shipping conditions
- However, the choice of the ageing method will be important for the achieved results and the conclusions made



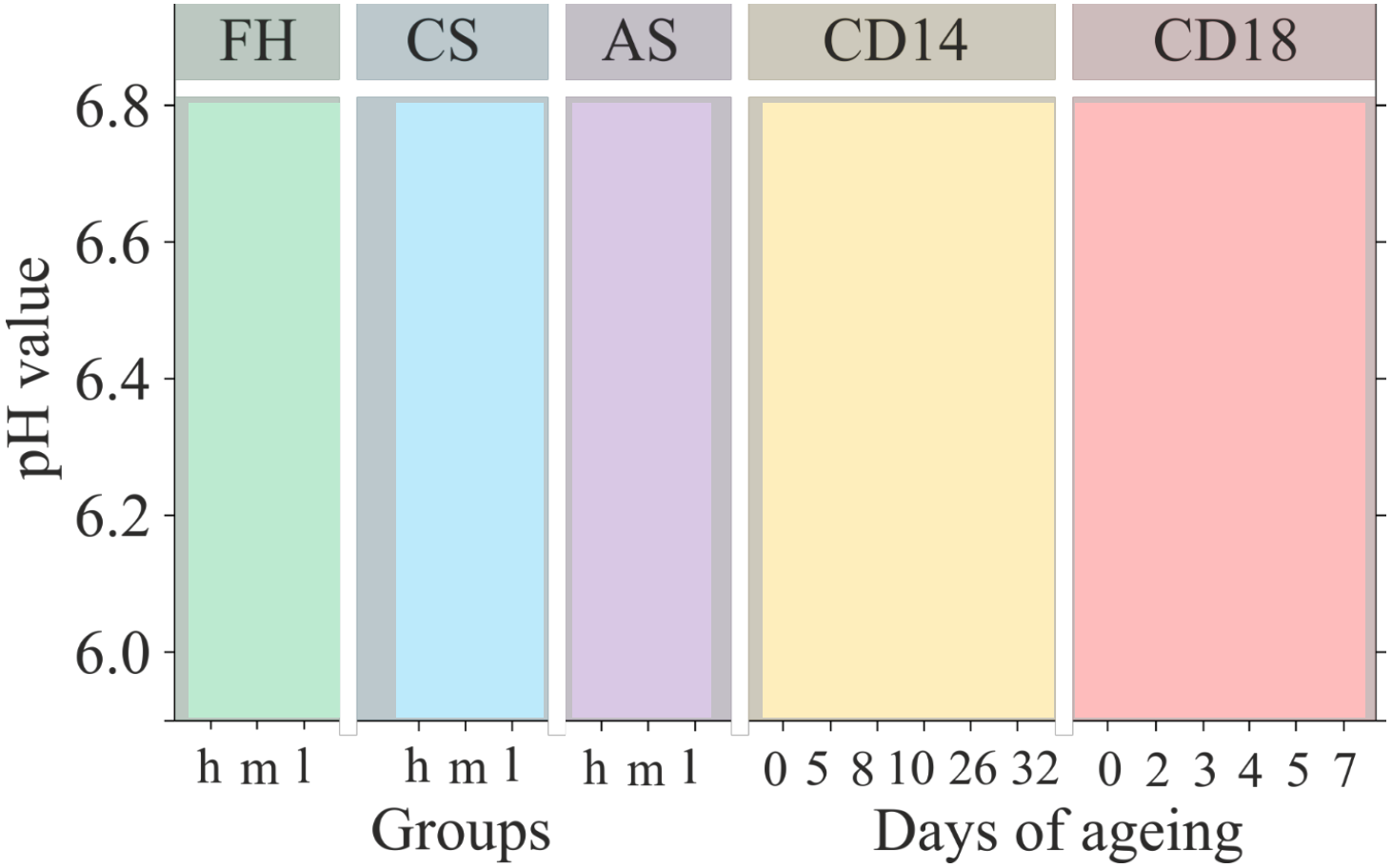
Thank you for your attention!



Picture: Michael Grau (2008)

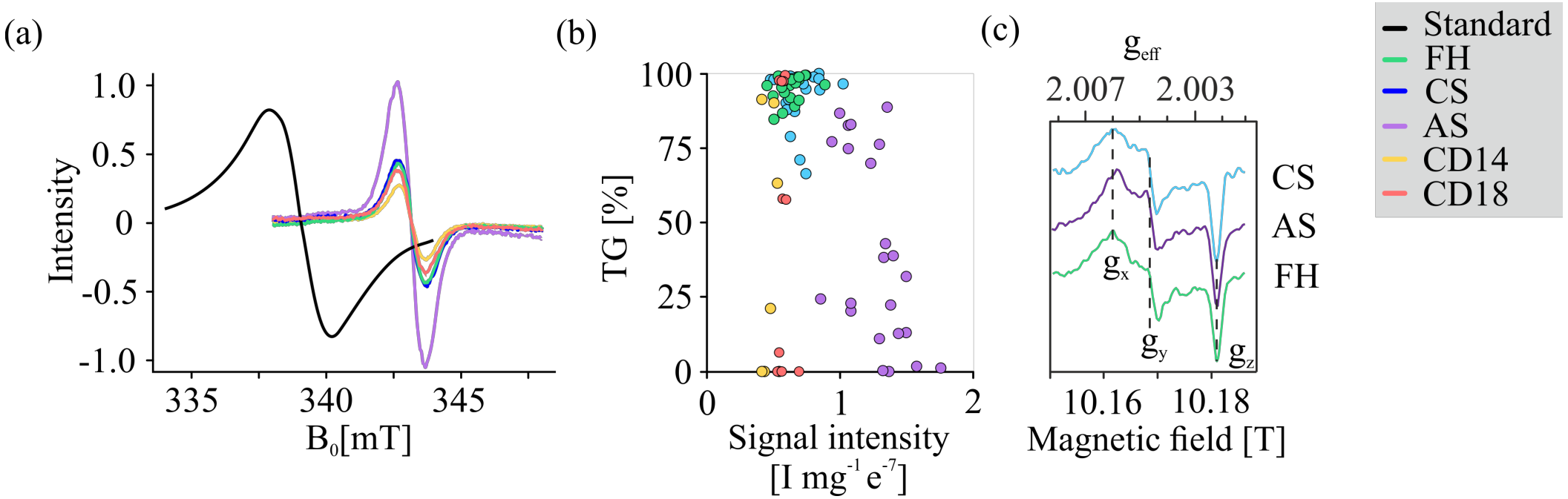
https://www.seedtest.org/en/event.html

pH change during seed ageing



- Ambient storage (AS)
- Cold storage (CS)
- Freshly harvested (FH)
- CD at 14%
- CD at 18%

X-band EPR spectroscope at 9.3 GHz



Standard procedures

FAO. (2014). *Genebank standards for plant genetic resources for food and agriculture. Food and Agriculture Organization of the United Nations, Rome.*
http://www.fao.org/agriculture/crops/core-themes/theme/seeds-pgr/en/