



Banking on Diversity for a Food Secure World

Hugh Bunting Memorial
Lecture

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Overview

- Fears are growing about how we can sustainably feed an expanding population in a rapidly changing world
- New crops and crop varieties continue to have a vital role to play
- Yet the genetic diversity needed to breed them - the biodiversity that feeds us - is under threat
- Several key global, policy, financial and technical initiatives aim to safeguard this critically important resource

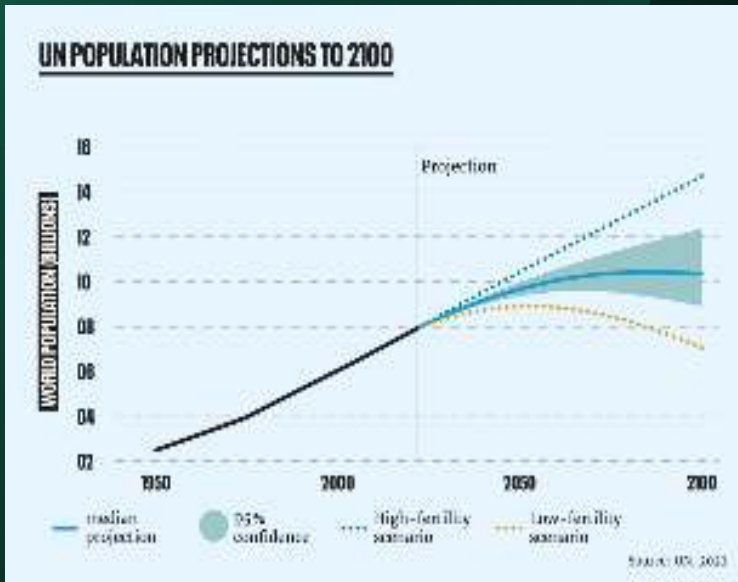


To start, a few depressingly familiar facts and figures

- Population to peak at 10.3bn in 2080s; 2bn > today
- 2023: approx 2.3bn people moderately or severely food insecure; 1 in 11 faced hunger (1 in 5 in Africa)
- 2022: 69m children under 5 stunted
- 2022: 5.8% of adults worldwide obese
- 57% increase in global food demand by 2050 compared to 2015

BUT

- 1/3 of all food produced is wasted
- 1/3 world cereal harvest is fed to livestock
- Our natural resources are under pressure:
 - Per capita fresh water is diminishing; agriculture uses 75% of it.
 - 33% of global agricultural soils are degraded

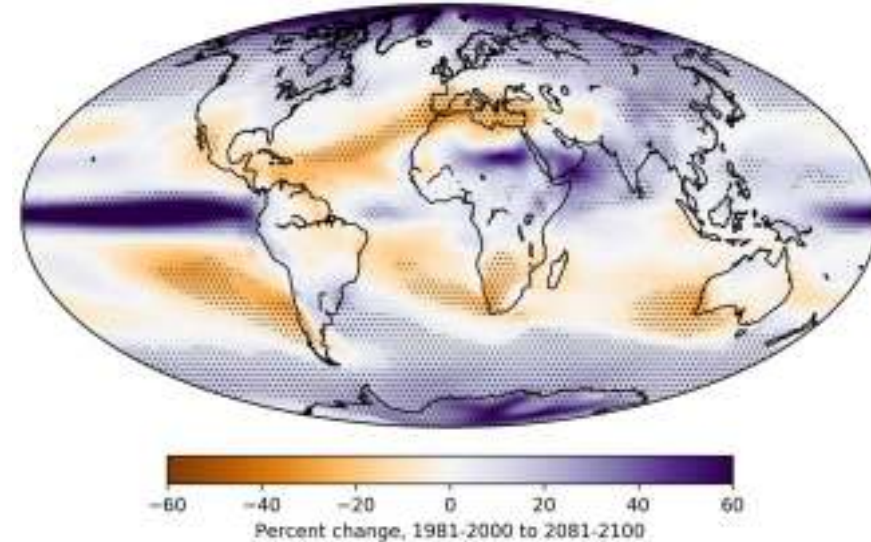


Sources: FAO, IFAD, UNICEF, WFP, WHO, 2024: United Nations Department of Economic and Social Affairs, 2024; Osendarp et al., 2022; , Falcon et al. 2022; Hasegawa et al. 2022; Deutsch et al. 2018; World Bank, 2010.

...and climate change:

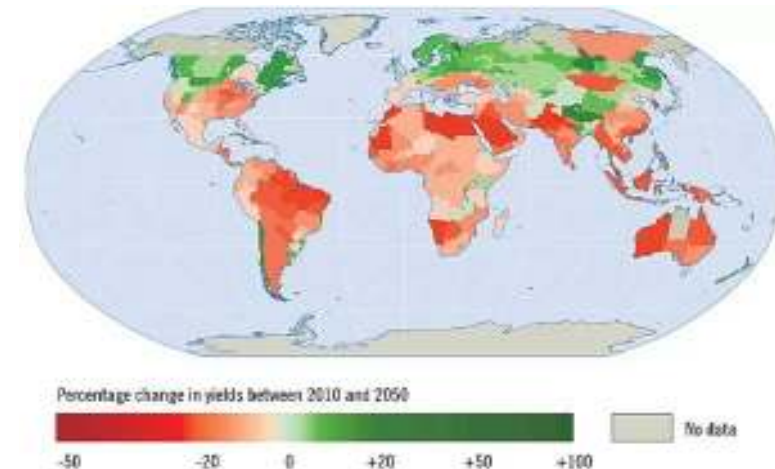
- Major losers: Amazon, S Africa, Mediterranean, S and SE Asia
- Possible winners: N Europe, N America, E Asia
- BUT: losers outweigh winners, and all are subject to increasing frequency of extreme weather events
- Without CO₂ fertilization, effective adaptation, and genetic improvement, each 1°C rise would reduce global wheat yields 6.0%, rice 3.2%, maize 7.4%, and soybean 3.1%*

Impact on precipitation



Hausfather, Carbon Brief, 2018

Impact of 2°C rise on crop productivity



Source: World Bank 2010

*Proc Natl Acad Sci U S A 2017 ;114(35):9326–9331. doi: [10.1073/pnas.1701762114](https://doi.org/10.1073/pnas.1701762114)

**"TOWARDS A WORLD
WITHOUT HUNGER:
MEETING THE
CHALLENGE OF FOOD
AND NUTRITION
SECURITY - AN URGENT
CALL FOR RESEARCH
AND INNOVATION "**

**120 Nobel Prize Laureates
30 Food Prize Laureates,**

March 2025

Today's challenges of access to food will be exacerbated by production challenges tomorrow. We are not on track to meet future food needs. Not even close. While much can and needs to be done to improve the flow of food to those in need, food production and accessibility must rise sharply and sustainably by mid-century, particularly where hunger and malnutrition are most severe...





Why is diversity important

- Diverse diets help promote human health
- Stable and resilient farming systems
- Historical, heritage and cultural value
- and ...

Phtos: CGIAR



Source of traits for crop improvement

Breeding new varieties with, for example:

- Higher and more stable yield
- Greater pest and disease resistance or tolerance
- Improved nutritional, storage and processing quality
- Better adaptation to, e.g. high temperatures, drought, water-logging, salinity ...
- Increased nutrient-use efficiency
- Reduced GHG emissions and increased carbon sequestration
- Greater resilience to extreme weather events



Where does genetic diversity come from?

- Landraces and farmer varieties domesticated and improved over 10,000 years; a continuing process
- Crop wild relatives – the progenitors of crops and their close relatives
- Commercial varieties, both current and obsolete
- Induced mutants, breeding lines, gene edited lines, etc.

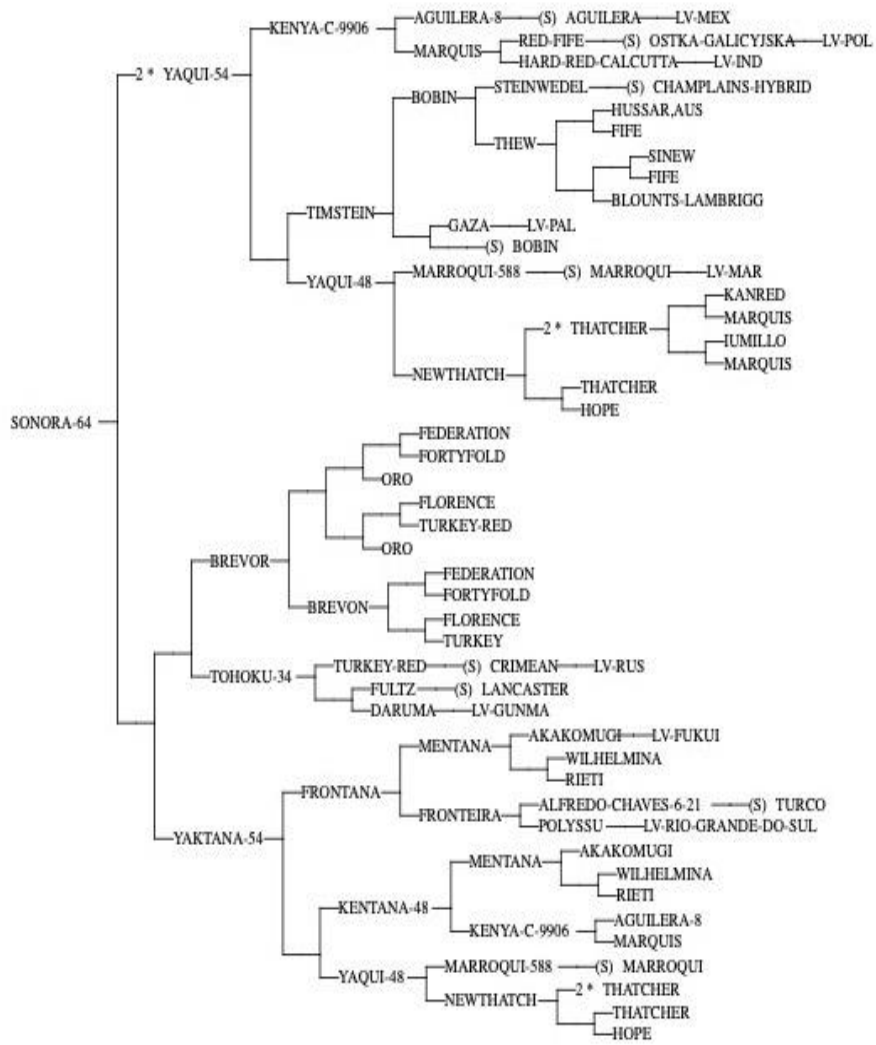




Extent of genetic diversity: the example of rice

- Rice has approximately 50,000 genes
- Average gene $\approx 3,000$ base pairs
- Assuming ≈ 10 functionally different variants per gene
- $\approx 10^{37,000}$ distinct variants
- Number of atoms in the known universe $\approx 10^{82}$
- If 99.9999% of variants are lethal $\approx 10^{37,000-8}$ distinct viable variants.

High levels of interdependence among nations



Pedigree of Sonora 64 - released 1964
 Approx 30 landraces and varieties from 15 countries

Global average*

- 70% of crops grown nationally originated elsewhere

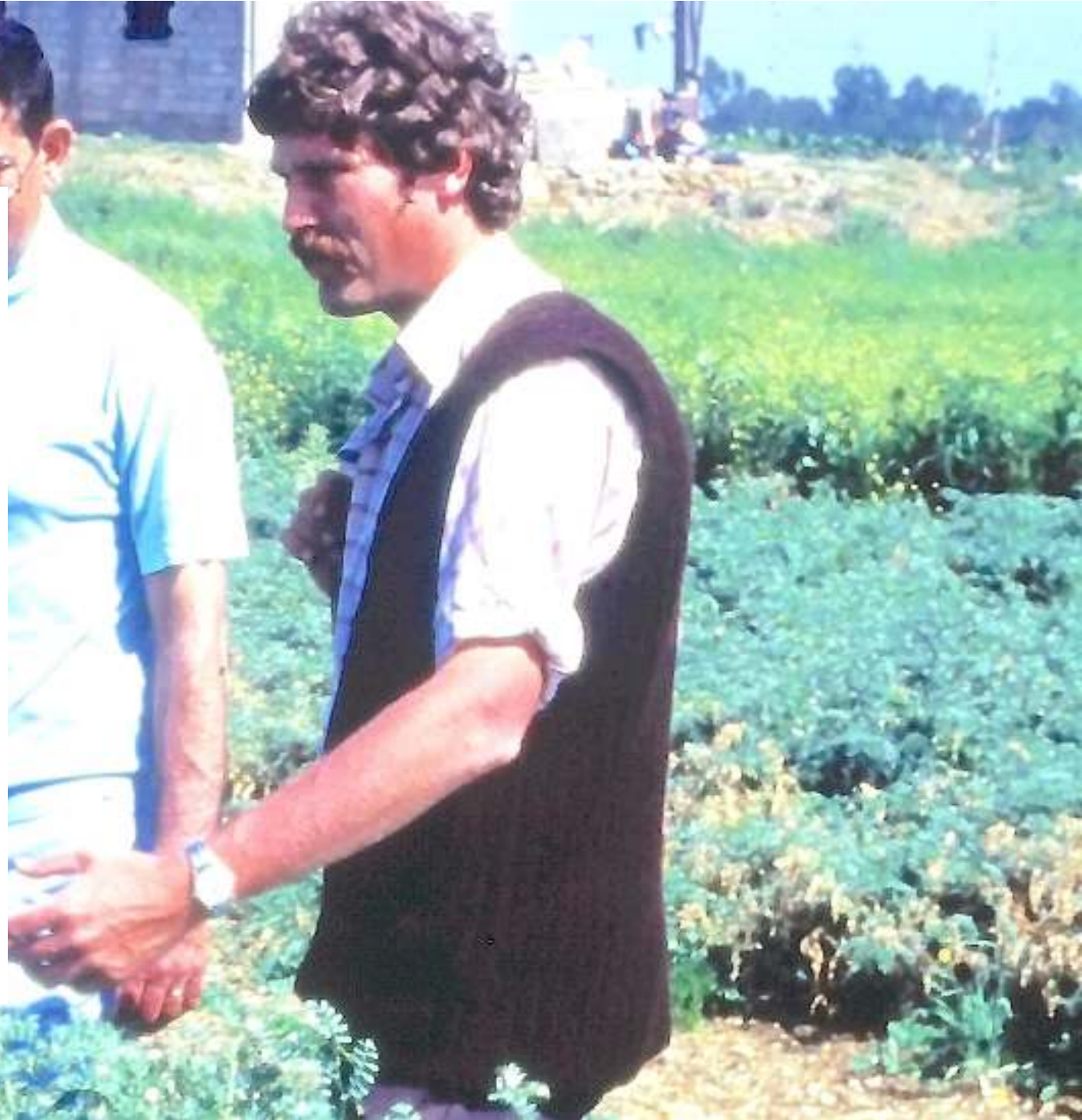
Modern crop varieties have parents that originated in many different countries:

- 1980s CIMMYT Veery Wheat lines: > 3,000 crosses between 51 parents from 26 countries in 5 continents

* Khoury et al. 2016. Origins of food crops connect countries worldwide
Proc. R. Soc. B. **283** 20160792

Recognising the importance of diversity - a personal story

- Initiated pulse breeding programme for WANA region, 1974, Lebanon
- Collected lentils, chickpeas and faba beans in Afghanistan, Egypt, Iraq, Syria, Lebanon, Turkey, Ethiopia
- Lebanese Civil war - moved collections to Syria, under duress
- Basis of ICARDA's legume collections, Aleppo genebank, Syria ...





But we are losing crop diversity:

Diversity is threatened in the wild as habitats are degraded or lost

On farmers' fields as:

- Farming systems adapt to climate change
- Farmers switch to more economic varieties and crops
- Consumer demands change

And even in genebanks, due to

- Natural disasters (e.g. Philippines, flood, fire)
- War and civil strife (e.g. Afghanistan, Iraq, Syria)
- Lack of funding, mismanagement

*Khoury et al. 2021 Crop genetic erosion: understanding and responding to loss of crop diversity. New Phytologist 233-1 pp 84-118

What can we do about it?

in situ conservation in the wild

- Appropriate for crop wild relatives
- Conserves evolutionary processes
- Special management regimes, environmental land management schemes
- Reserves specifically designed for crop wild relatives: e.g.
 - Sierra de Manantlan Reserve, S.W. Mexico (wild maize)
 - Nokrek Biosphere Reserve, N.E. India (wild citrus spp.)
 - Kasdagi National Park, W. Turkey (wild pear, chestnut)



'Conservation' on farmers fields

- Varieties / landraces continue to evolve under farmer and natural selection
- Specific traits and alleles conserved
- Incentives required for farmers to maintain 'obsolete' varieties, e.g.:
 - new specialty markets
 - new products
 - special payments



Ex situ conservation in genebanks

- seed banks
- field gene banks
- *in-vitro* tissue culture banks
- cryopreservation
(20% crops cannot be conserved as seeds)
- pollen, lyophilized leaves etc.
- *in silico*



Why *ex situ* conservation is critical

- Many genetic resources only exist *ex situ*
- Safety net for reintroduction following a natural or man-made disaster e.g.:
 - After the tsunami in Aceh (2004), IRRI supplied seed of local rice varieties
 - Rwanda (post-1994 genocide): local bean varieties lost during conflict reintroduced by CIAT from Colombia

and

It provides a readily accessible source of genes and genetic information for crop improvement, obviating the need to continually recollect



Status of *ex situ* conservation

- Today approx. 1,700 genebanks worldwide
- >3,000 botanical gardens: 350 in 75 countries have seed banks
- 5.8 million samples held under medium-term (+5°C) and long-term (-18°C) storage

Status of conservation in crop genebanks

Of the approx. 4m accessions of known status approx.:

- 90% stored as seed
- 35% farmers' varieties/landraces
- 18% crop wild relatives
- 46% improved varieties and breeding materials
- Cereals 41%
- Pulses 12%



Examples of CGIAR Centre collections



- CGIAR total: 760,000 accessions in 35 collections
- Approx. 100,000 germplasm samples distributed freely per year to >120 countries

Crop	International Centre	Number of Accessions
Agroforestry spp.	CIFOR-ICRAF	16,000* (220 spp.)
Banana	Bioversity International**	2,000
Barley	ICARDA	32,000
Beans	CIAT**	38,000
Forages	CIAT + ILRI + ICARDA	66,000 (1,500 spp.)
Maize	CIMMYT	29,000
Potato	CIP	7,000
Rice	IRRI + AfricaRice	148,000
Wheat	CIMMYT + ICARDA	196,000

* approx. 7,000 in seed bank, 9,000 in field genebank

** now Alliance of Bioversity and CIAT

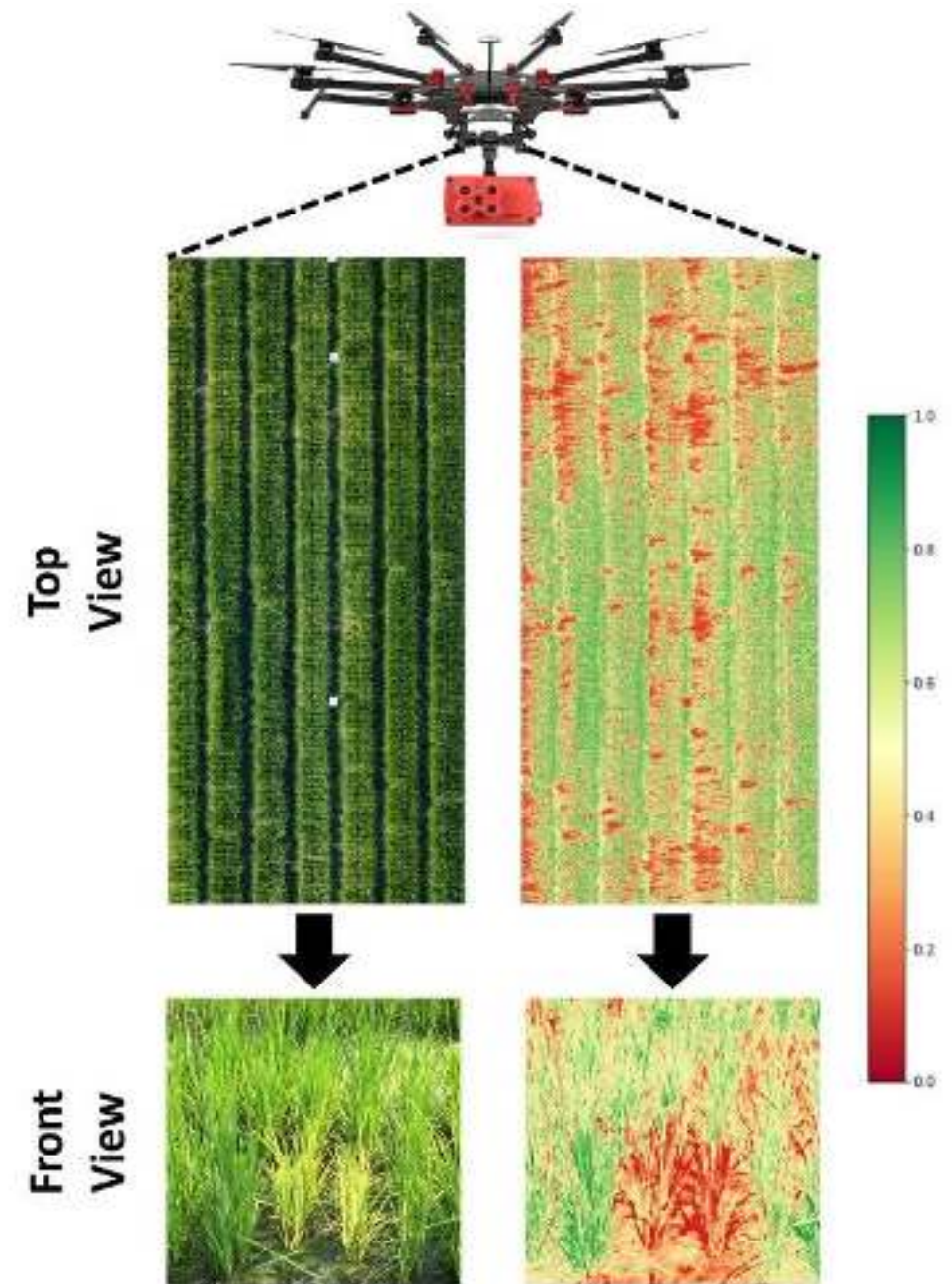
Source: CGIAR Genebank Platform 2021

<i>Rhizobia</i> Culture Collections:	ICRISAT	819 strains
	ICARDA	1,380 strains

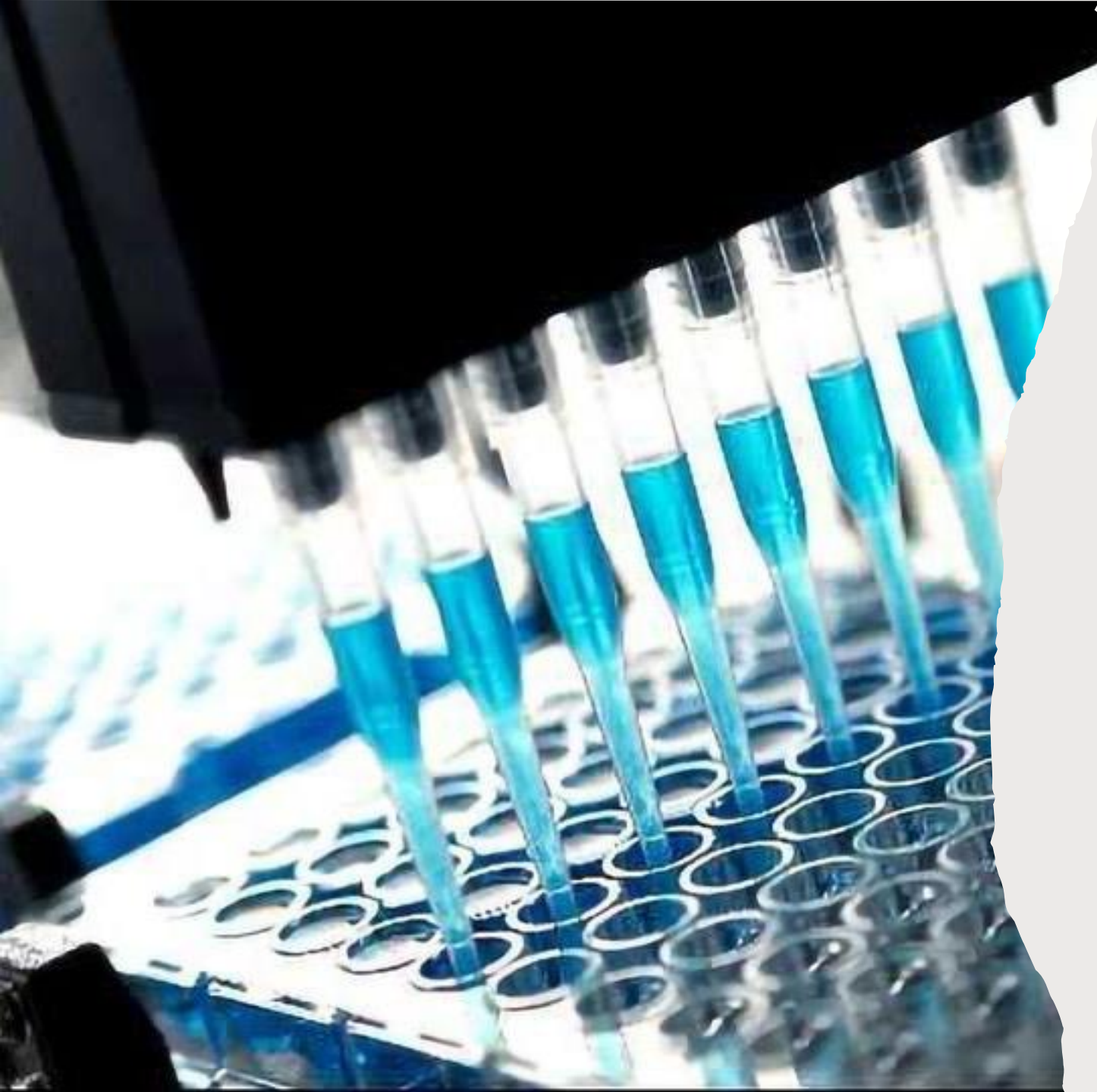
Genebanks set to become even more important in a changing world

Rapidly increasing ability to:

- generate data on important traits: high-throughput automated phenotyping, image-based systems, remote sensing, drones ...
- generate vast amounts of genomic information: next-generation sequencing, high density mapping...
- handle very large datasets: increasing computer power, AI ...



Using drones to screen for rice hoja blanca virus (RHBV) - CIAT



Future of genebanks

- Wild relatives, minor ‘opportunity’ crops
- Clonal crops and recalcitrant seeded species: cryopreservation
- Special trait collections, e.g. of drought or heat tolerant species
- Collections of special genetic interest, e.g. mapping and GWAS populations, cytogenetic stocks, etc.

THE INTERNATIONAL TREATY
ON PLANT GENETIC RESOURCES
FOR FOOD AND AGRICULTURE



Food and Agriculture Organization of the United Nations

Who owns genetic resources? access and benefit-sharing

- Convention on Biological Diversity, 1993
 - national sovereignty → bilateralism
 - not suited to agriculture → slowdown in collecting and exchange
- International Treaty on Plant Genetic Resources, 2004
 - Ratified by 152 states plus the EU
 - Covers conservation, access and benefit-sharing
 - Multilateral system



Multilateral system for access and benefit-sharing

- Covers 35 crops and 30 forages
- Exchange using Standard Material Transfer Agreement
- Mandatory payment if access to product is restricted by IPR*
- Benefit-Sharing Fund
- Further negotiations: coverage, DSI, Farmers' Rights, benefit-sharing...

*Currently 0.7% of sales

Resourcing Conservation: The Global Crop Diversity Trust

- National and international funding concerns, 1990s
- Crop Trust founded 2004 to fund the global system of *ex situ* conservation *in perpetuity*
- Endowment fund approx. £260m, with approx. £7m annual offtake.
- Target endowment £500m





Crop Trust, cont...

- Long-term grants to date for 18 crops in 11 institutions.
- Special projects: regeneration, underused/opportunity crops wild relatives, etc.
- information systems: GRIN-Global, Genesys (<https://www.genesys-pgr.org/>)
- Svalbard Global Seed Vault

Svalbard Global Seed Vault

- Unique international safety back-up facility, opened Feb 2008
- Norwegian government initiative - with NORGEN and Global Crop Diversity Trust
- On Spitsbergen, 1,300 km from N. Pole, 130 masl
- Permafrost at -3°C & cooled to -18°C

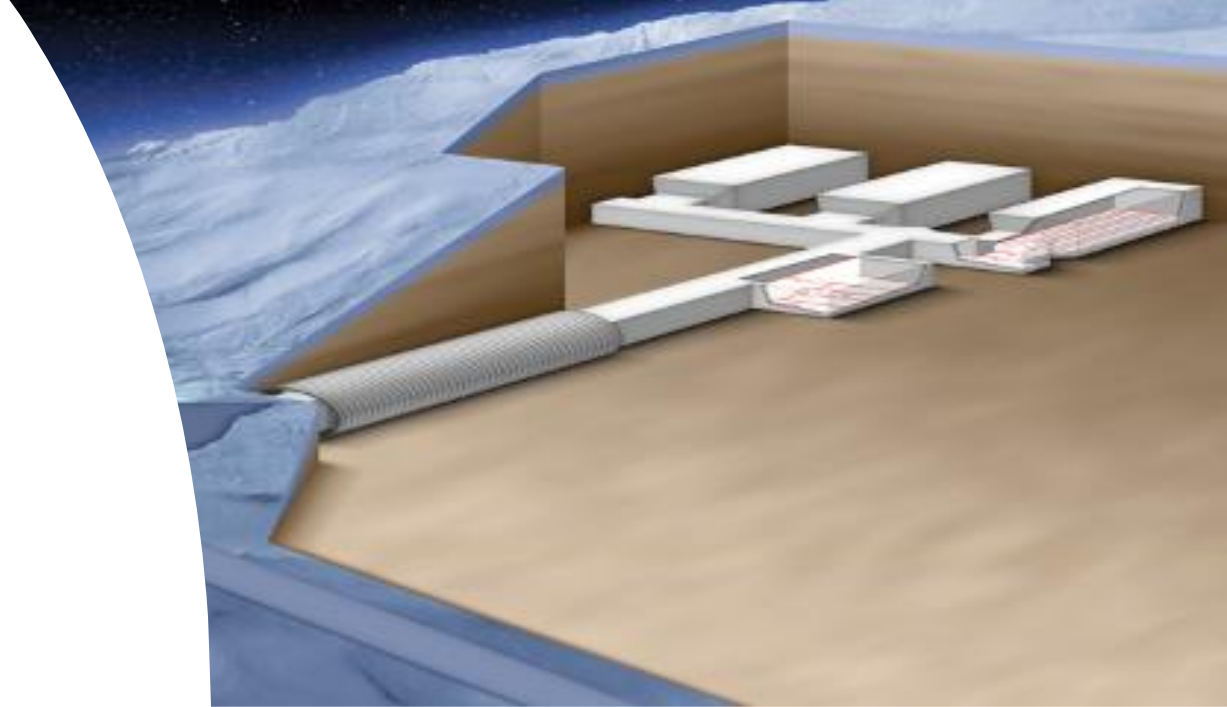


Svalbard Global Seed Vault, cont...

- Tunnel: 95 m. with 3 vaults
- Total capacity 4.5m. samples
- As of September 2025:
 - 1.33 million seed samples,
 - of 6,297 species,
 - from 123 genebanks in 91 countries

£20m to build & £750k total annual maintenance and operating cost:

Arguably the world's best insurance policy!



Coming full circle

- Material I collected in 1970s, kept in ICARDA genebank, Aleppo, Syria
- Collection safety duplicated in Svalbard 2008 - 2012
- ICARDA genebank destroyed 2014
- Material send from Svalbard to Morocco and Lebanon for regeneration and storage: 2015, 2017 and 2019
- 2022 ICARDA opened new state of the art genebank in Rabat.
- Some of the 1970s lines grown out in Morocco in 2024



Wrapping up

Diversity underpins sustainable and resilient agriculture, enabling adaptation to future challenges

Crops and varieties that are higher yielding, more nutritious and better able to cope with climate change are essential – as are improved ways to grow them

The genetic diversity we need to breed better crops is under threat and must be conserved

Various developments over the past 20 years in science, technology, policy, and financing, give hope

Unless we are successful, we risk severely limiting our options for sustainably meeting global food security, and will impoverish future generations





Many thanks
for your
attention