CONSULTING SERVICES

Horticultural Genetic Resources Conservation & Use with a Focus on Meeting the Challenges Posed by the Climate Change

Ramanatha Rao

Former Senior Scientist, Bioversity International & Co-Founder, Global Research-for-development Support Ventures (GRSV), Bengaluru

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Introduction

- **Profitable to diversify into horticultural crops**
- **Production of horticultural crops - Faster than cereals**
- **1960 - 2000, area under horticultural crops - more than doubled**
- **High-value horticulture relies on non-traditional species, often on exotics**
- **Need to increase value of local horticultural species**

- **First genebank- In Leningrad (now St Petersburg) in 1920**
- **Tremendous effort worldwide since**
- ***In situ* ≈≈≈ *Ex situ***
- **Over 1750 individual genebanks - 7.4 million accessions + Svalbard Global Seed Vault**
- **Degree of duplication???**
- **PGR is a fundamental input for productivity, diversity, health & quality of agriculture & food & feed production & our environment**

- **Efforts conserve horticultural genetic resources (HGR)**
- **National Gene Bank, NBPGR**
- **Several central & regional institutes (IIHR etc.)**

- **To date, most efforts have focused on *ex situ* conservation**
- **Increased efforts needed on *in situ* conservation**

  ➔ **With links to each other – in fact, a "Continuum of Conservation"**

To facilitate

- **Conservation of larger pool of species & genetic diversity**
- **Utilization in genetic improvement**
- **Improved access to farmers & communities, as well as to pharma- & nutraceutical & & seed industry**
- **To adapt to changing climate & mitigate its negative effects**

Given this background

➔ **What could be priorities, challenges & the way for forward?**

Exploration & Collecting

- **Much HGR have been collected & conserved**
- **What more could be collected?**
- **Despite progress made, many challenges**
  - **HGR comprises of many diverse tree & shrub species**
  - **Little known (described) wild species (medicinal plants)**
  - **Poorly documented underused & rare fruit & vegetable species**

For example:

1. Scientists from the Royal Botanic Gardens, Kew & Imperial College London, & partners from the UK & the US have identified 1,044 plant species that have potential to be a source of vitamins Ref: Cantwell-Jones, A., Ball, J., Collar, D. et al. 2022. Global plant diversity as a reservoir of micronutrients for humanity. **Nature Plants**. Published: 24 February 2022 https://doi.org/10.1038/s41477-022-01100-6

2. Increased efforts in exploring & collecting of underutilized fruit & other horticultural plant species

Constraints & What Could Be Done

- **Lack of expertise in botany & taxonomy**
  - **Motivate younger researchers**
- **Weak links between genebank & other institutions & users**
  - **Promote a 'Systems approach' – is defined as "Sets of interconnected elements and processes that result in a particular function or set of functions".**
- **Such an approach helps identify key issues confronting conservation & use of PGR (See: *DOI : 10.5958/0976-1926.2016.00039.5* & *https://www.sciencedirect.com/science/article/pii/S1360138521002582*)**

- **Difficulties in accessing & using PGR information**
  - **Improve access to information & sharing it & mapping by all those who need it**

Exploration & Collecting contd.

- **Difficulties in identifying gaps in collections**
  - **Integrate passport, characterization & evaluation data**
  - **Analyse & identify areas/sites rich in diversity to facilitate target collecting (see Gap Analysis - https://doi.org/10.1007/s10531-021-02225-4; https://doi.org/10.1016/j.biocon.2021.109439 etc.)**

- **Revise objectives of exploration & collecting**
  - **Collect genetic diversity & not just elite material**
  - **Gather information to assist evaluating the site for possible *in situ* conservation site**

In situ/on-farm conservation

- Conservation of ecosystems & natural habitats
- Enable biodiversity to maintain itself within the context of its native ecosystem
- *In situ*/on-farm conservation, along with home gardens, is of high relevance for tropical plant species
- Wild species & crop wild relatives (especially tree & perennial plant species) are main candidates for conservation in situ

Needs involvement of farmers & communities

- Internalize with farmers' production activities
- Overcome the difficulty in changing the mind-set of PGR researchers

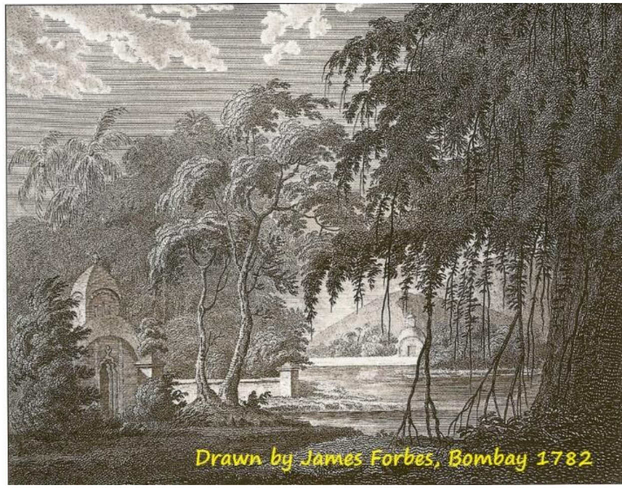
Some challenges & what can be done

- **Poor understating of local concerns**
  - **Better understand local needs & local uses**
  - **Avoid top-down-approach**

- **Lack of attention to how the farmers/locals perceive & value genetic diversity**
  - **Understand why farmers either value or not value crop diversity, local seed systems etc.**
  - **Understand & promote other to understand scientific basis for in situ conservation**

- **Lack understanding of the contribution of *in situ* conservation of crops to ecosystem functions**
  - **Explain/demonstrate contribution of on-farm/*in situ* conservation to ecosystem functions, e.g.**
    - **Water regulation by fruit tree species**
    - **Pharmacological resources by medicinal plants**
    - **Pollination services by promoting bees etc.**

- **On-farm/*in situ* conservation not feasible in all situations**
  - **Determine the feasibility of In situ/on-farm conservation in a given situation**
  - **Do not promote it as a universal solution**
  - **Link with ex situ conservation & integrate it as component of a complementary conservation strategy**
- **Lack of understanding of home gardens(HG)/sacred groves (SG) in conservation of HGR**
  - **One HG/SG may be inconsequential but a community of them does**
  - **Explore how HG/SG systems be integrated into broader conservation strategy**
- **Limited allocation of resources- financial & human**
  - **Demonstrate the feasibility & importance**
  - **Generate more funds & approvals for optimal level of staffing**
  - **Develop strategies to improve human resources needed**



Ex situ conservation

***Ex situ* conservation: away from its normal native habitat**

- **Rescue & preservation of threatened genetic material & use**

***Ex situ* conservation methods include:**

- **Whole plants in the field (field genebank)**
- **Orthodox seeds in clod stores (seed genebank)**
- **Clonally propagated plants as tissue cultures under slow growth (*in vitro* genebank)**
- **Non-orthodox seed & vegetatively propagated plants, pollen & DNA under cryopreservation (Cryo-genebank)**

Standards for conservation of orthodox seeds, non-orthodox seeds & vegetatively propagated materials etc.

Ex situ conservation (contd.)

Field Genebank: For species that

- **Produce non-orthodox (recalcitrant) or intermediate seeds**
- **Produce very few seeds**
- **Vegetatively propagated**
- **With long juvenile periods such as fruit trees**

Research issues or challenges:

- **FBG can be very costly in terms resources need- land, water, human etc.**
- **FGB is not just a "farm" - you are not looking at productivity increase, but at preservation of genetic identity & genetic diversity**
- **Need science based design, establishment & management procedures**
- **There can genetic erosion in FGB, hence watch out for it**

→ See: Mohd Said Saad and Ramanatha Rao, eds. 2001. Establishment and Management of Field Genebank, a Training Manual. IPGRI-APO, Serdang https://www.bioversityinternational.org/e-library/publications/detail/establishment-and-management-of-field-genebank/

Seed Genebanks: For species with orthodox seeds

i.e. seeds that can be dried to low moisture contents & stored in cold stores

- **The most common method of *ex situ* conservation of PGR**
- **Extensive genebank standards are available**

Some of the challenges:

- **Research on longevity of seeds**
- **Less than expected longevity at - $20^{\circ}C$**
- **Research required to understand differential storability**

Some solutions

- **Consider expansion of storage in LN2**
- **Need understanding potential changes in viability of seeds stored in LN2**

Ex situ conservation (contd.)

- **Many genebanks are poorly managed & just as seed stores**
  - **Develop a set of tools to be used to enhance quality, efficiency, & cost-effectiveness of genebank operations**
  - **Improve ease of access to information & knowledge on genebank holdings,**
  - **Promote interaction between genebanks & farmers (for e.g. providing landrace, using farms for GR regeneration, etc.)**
  - **Enhance the level of public awareness & interest agricultural biodiversity**

- **Difficulties in using modern tools for managing & using accessions conserved**
  - **Integrate genotyping & sequencing into the genebank activities**
  - **Improve effectiveness of documenting genetic identity of accessions conserved, tracking seed quantity**
  - **Streamline distribution needs & supply, regeneration processes & timing, identification of duplicates & rationalization of collections etc.**

In vitro slow growth storage

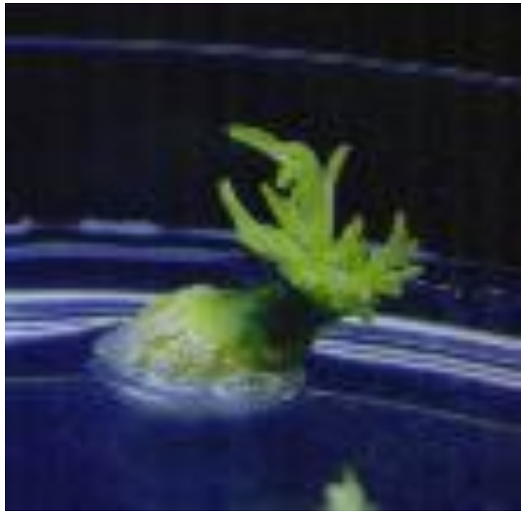
Cost-effective *in vitro* culture, multiplication, regeneration & propagation system is prerequisite

A few challenges & the way forward are:

- **Improve culturing without contamination**
- **Develop appropriate growth media**
- **Identify interspecific, intraspecific & inter-varietal differences in response to *in vitro* storage**
- **Customize growth media for unique plant groups**

- ***In vitro* slow growth is really a not a method conservation (see Wang et al. 2022. Horticulture Research, 9, uhab036, https://doi.org/10.1093/hr/uhab036**

- **Material conserved using slow growth techniques should eventually move into cryo-genebanks**



Cryopreservation

- Mainly for non-orthodox seeded & seed producing species
- Many of HGR species belong to this category
- More advanced for veg. propagated than non-orthodox seeded
- Vast amount of information & guidelines available

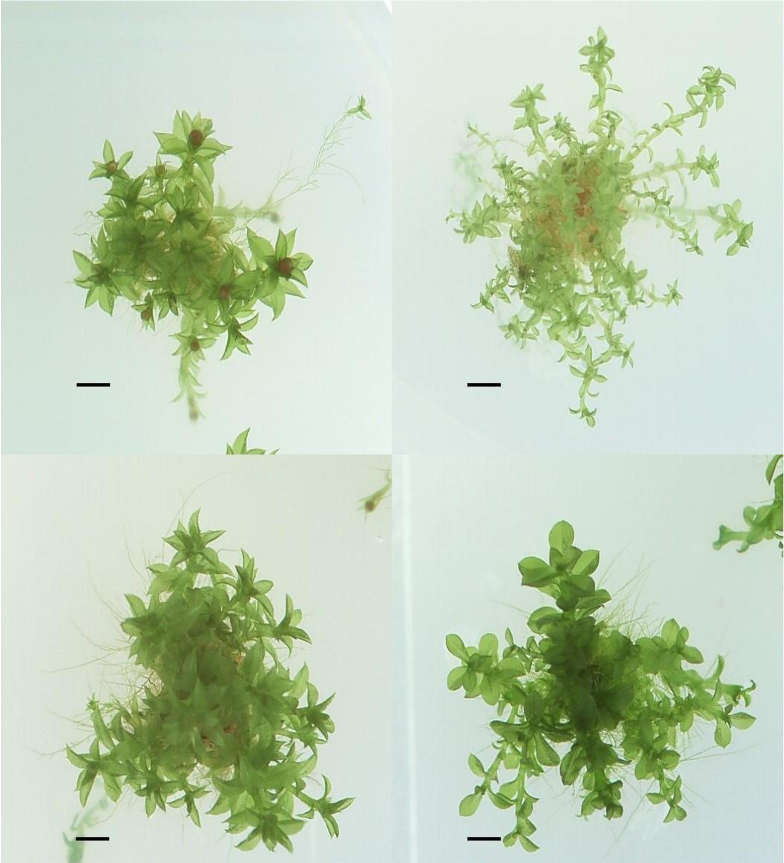
A few challenges & actions needed:

- Protocols for conserving tropical species, especially wood perennials
- Protocols for conserving seeds of many recalcitrant HGR species
- Make cryopreservation more secure & cost-effective technology
- Promote research on: extreme sensitivity to desiccation & effects of exposure to very low temperatures, etc.
- Consider cryopreservation of orthodox seeded species as a cost-effective & longer term storage option than convectional methods

(see: Int. J. Mol. Sci. 2021, 22(11), 6157 https://doi.org/10.3390/ijms22116157;
Plant Cell Tiss Organ Cult 2221, 144, 21–34 https://doi.org/10.1007/s11240-020-01846-x;
Plant Cell Tiss Organ Cult 144, 35–48 (2021). https://doi.org/10.1007/s11240-020-01884-5;
Plants 2021, 10(12), 2744; https://doi.org/10.3390/plants10122744;
Plants 2021, 10(12), 2627; https://doi.org/10.3390/plants10122627; :FAO. 2014. Genebank Standards for Plant Genetic Resources for Food and Agriculture. Rev. ed. Rome)

Cryopreservation (contd.)

- **Difficulties in regeneration of cryopreserved material**
  - **Develop solutions for many species, including HGR, for regeneration after thawing, rewarming, etc.**
  - **Promote research on survival of cells or tissues after cryopreservation that can readily succumb due to different environmental agents because they have been injured by the dehydration or temperature change during the cryopreservation procedure**
  - **Special consideration must be given to certain plant species that cannot be conserved using any other methods**

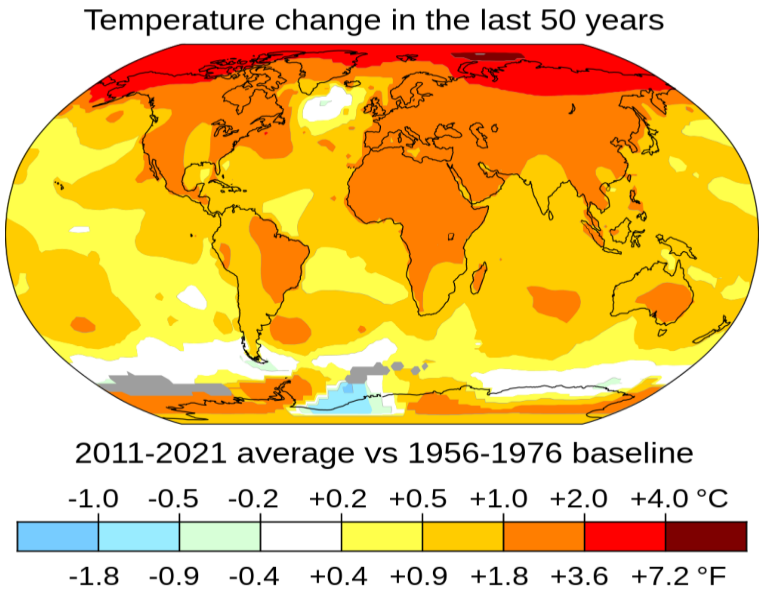


Climate Change (CC)

In General, agriculture is extremely vulnerable to CC

- ❑ Higher temperatures result yield decline in most crops
- ❑ Encourages weed & pest to proliferate
- ❑ Changes in precipitation patterns leading to

➔increase the short-term crop failures & long-term production decline



Similar effects on horticultural crops:

- ➢ Decrease chilling & inhibit bloom & fruit set
- ➢ Lead to high temperature & wind during bloom period
- ➢ Increased evapo-transpiration rates leading to water deficits
- ➢ Increase problems with heat stress
- ➢ Established varieties of fruits, vegetables & ornamentals may perform poorly
- ➢Pollination will be affected adversely because of higher temperature
- ➢ Changes in quality may occur, especially in vegetables & fruits
- ➢ Coastal plantations may be affected by increased/decreased salinity

For more information see (sample references)

1. Sthapit BR, Ramanatha Rao V, Sthapit SR. 2012. Tropical Fruit Tree Species & Climate Change. Bioversity International, New Delhi, India; https://www.bioversityinternational.org/e-library/publications/detail/tropical-fruit-tree-species-and-climate-change/

2. Snyder R. 2017. Horticulturae 3: 27; https://pdfs.semanticscholar.org/e8d1/168af4daad8409bc39efbf23a42156f933f6.pdf

3. Dutta, S. 2013. Intl. J. Sci. Envt. 2(4): 661– 671; https://www.ijset.net/journal/139.pdf

4. Rituparna et al. 2021. The Pharma Innovation Journal 2021; 10(12): 640-644; http://www.thepharmajournal.com/;

So, What next?

Need cultivars that can–

- **Tolerate/adapt to high temperature**
- **Compete better with weeds**
- **Tolerate/resist changing pests**
- **Be water-use efficient**
- **Perform well in terms of quality & quantity under 'pressure'**

➔ Practise climate-smart horticulture balancing financial, social & ecological elements, including sequestration of carbon

See: 1. Toan Khac Nguyen et al. 2019. Flower Res. J. (2019) 27(4) : 226-241; https://doi.org/10.11623/frj.2019.27.4.01
2. Verma et al. 2022. in Internet of Things and Its Applications. EAI/Springer. https://doi.org/10.1007/978-3-030-77528-5_15
3. FAO. 2015. Coping with climate change – the roles of genetic resources for food and agriculture. Rome. https://www.fao.org/3/i3866e/i3866e.pdf

➔ Better understanding of impacts of CC on yield, markets & rural incomes & mitigating the ill-effects

See: 1. Haque et al. (Eds.) 2022. Climate Change and Community Resilience. Springer. https://doi.org/10.1007/978-981-16-0680-9
2. Kamini Gautam et al. 2022. The XXIV International Grassland Congress October 25 -29 2021. https://uknowledge.uky.edu/igc/24/3-2/10

More information needed

- Impact on growth, development & flowering
- Shift in seasonality
- Shifts in pests & new pests

Climate Change & HGR – What could be specific needs?

***Ex situ* conservation:**

1.Safety duplication of *ex situ* conserved HGR

2.Climate proofing genebank maintenance & management

1. Change in priorities: Focus more on material for sites with serious effects of CC

2. Selection of site for FGB: Select sites that are predicted to have minimal CC effects

3. Maintenance: Anticipate CC effects on flowering/seed yield etc.

4. Infrastructure & facilities needed: Anticipate & plan for draining or irrigating, increased green houses/screen house etc.

4. Finance planning: Budget for protecting FGB from events such as flooding/drought, rise in pests & diseases

3. Characterization & evaluation (C & E)

1. Prediction of effects of CC not very precise; need to anticipate in based on available information & change characterization & evaluation processes accordingly

2. Based on available information CC, plan new screening & evaluation trails to identify potential cultivars/parents for future use

3. Advances in technologies for the high-throughput analyses of gene expression can help discriminating responses to different biotic & abiotic stresses & potential trade-offs

In situ/on-farm conservation: Anticipated effects

➔Changes in range & size of species distribution

e.g. Rana et al. 2021. Ecological Indicators Volume 121:107127; https://doi.org/10.1016/j.ecolind.2020.107127; Alexander 2022. Phil. Trans. R. Soc. B 377: 20210020. https://doi.org/10.1098/rstb.2021.0020

➔Changes in phenology

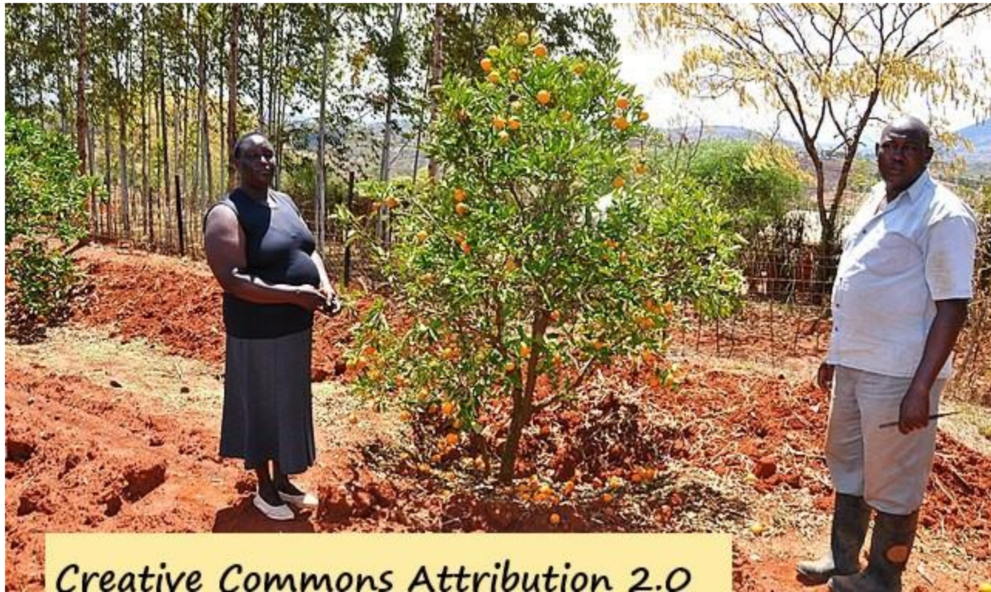
e.g., Sarkar et al. 2021. pp. 79-98 in India: Climate Change Impacts, Mitigation and Adaptation in Developing Countries. Springer Climate. Springer, Cham. https://doi.org/10.1007/978-3-030-67865-4_4

➔Standards for protected areas

e.g., Perrnino et al. 2022. Biology 2022, 11(2), 193; https://doi.org/10.3390/biology11020193

➔Evolutionary responses

e.g. Trew and Maclean. 2021. Global Ecol. Biogeogr. 30:768–783. https://doi.10.1111/geb.13272



Thank you for your attention