Conservation and Utilization of Tropical Fruit Tree Genetic Resources, with a focus on Utilization

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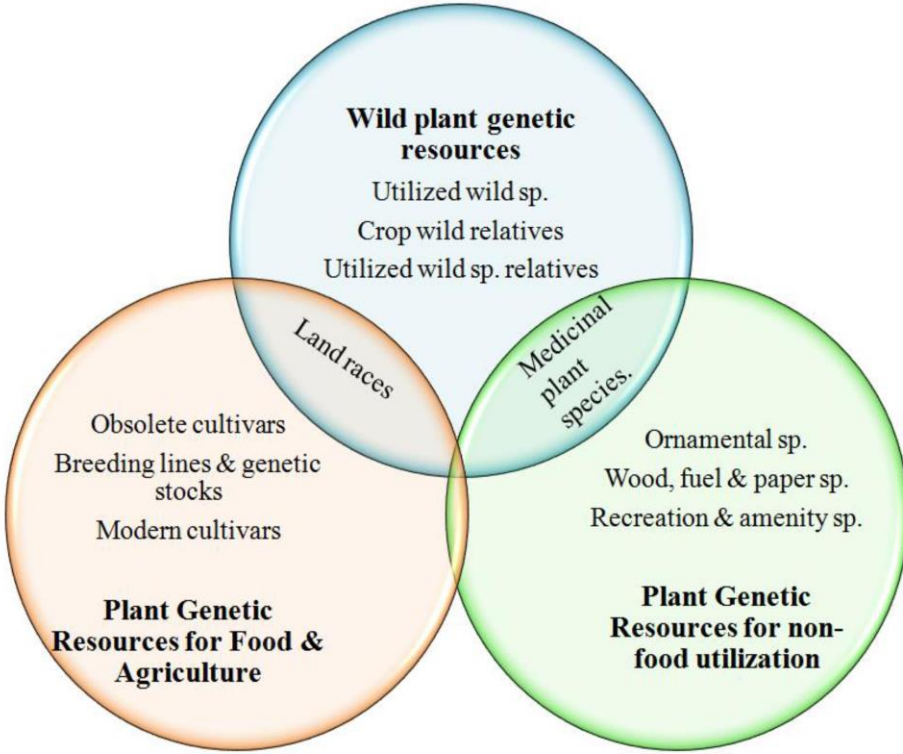
Introduction

- Production of horticultural crops has grown faster than other crops, for e.g., cereals
- Area under horticultural crops - more than doubled in recent decades
- Conservation of horticultural genetic resources- HGR- is essential for future developments in horticulture
- HGR comprises cultivated species and wild relatives of several horticultural crops – fruits (trees/shrubs; tropical, temperate etc.), vegetables, medicinal plants, spices etc., & it will require many more talks/experts to cover them all
- here the focus is on a small subsection of it – tropical fruit tree genetic resources – TFTGR in short
- Conservation of species & genetic diversity- GD) in TFT species is critical for future fruit crop improvement & their continued cultivation



Priyanka et al. 2021. Sustainability 13(12), 6743; https://doi.org/10.3390/su13126743

- Worldwide efforts to collect & conserve TFTGR have been underway for a long time
- In India, these efforts started with the establishment of the Agri-Horticultural Society in 1820
- Presently PGR work is mainly with the National Bureau of Plant Genetic resources - NBPGR - & its regional stations & fruit research institutes, for example, the Indian Horticultural Research Institute (IIHR), Central Plantation Crops Research Institute (CPCRI) etc.
- Almost all efforts to date have focused on *ex situ* conservation, with a few exceptions, like the *in situ* gene sanctuary for one citrus fruit in the Garo hills of Meghalaya,
  - Increased efforts are needed on *in situ* conservation
  - With links to each other

However

- Collecting & Conservation TFTGR received limited attention till the late 1990s
- Much less attention to characterising & utilising

➔ Due to inherent problems with TFTGR collecting & utilizing

Challenges in better conservation & use of TFTGR

- Focus on collecting elite material, poor representation of wild relatives
- Inadequate sample size
- Methods of collecting & transfer to genebank, etc.
- Availability of space and methods for conservation
- Limited GD conserved
- Poor characterization, evaluation & documentation
- Long gestation period
- Modern methods - marker-assisted, genetic transformation, gene-editing
  - ➔ Some progress was reported in grapes, citrus, apple, papaya etc., most TFT species yet to be developed
  - ➔ See Hortic Res 2021 8:166. https://doi.org/10.1038/s41438-021-00601-3 & Bioengineering 2022, 9:176. https://doi.org/10.3390/bioengineering9040176

Hence

- Conservation of a larger pool of species & GD of TFT
- Characterize & evaluation
- Genetic enhancement & access
- Better & faster crop improvement methods

Some examples of species that we are dealing with include:

Mango-*Mangifera indica*

Jackfruit - *Artocarpus heterophyllus*
By Augustus Binu, CC BY-SA 3.0

Avocado - *Persea americana* CC BY-SA 4.0

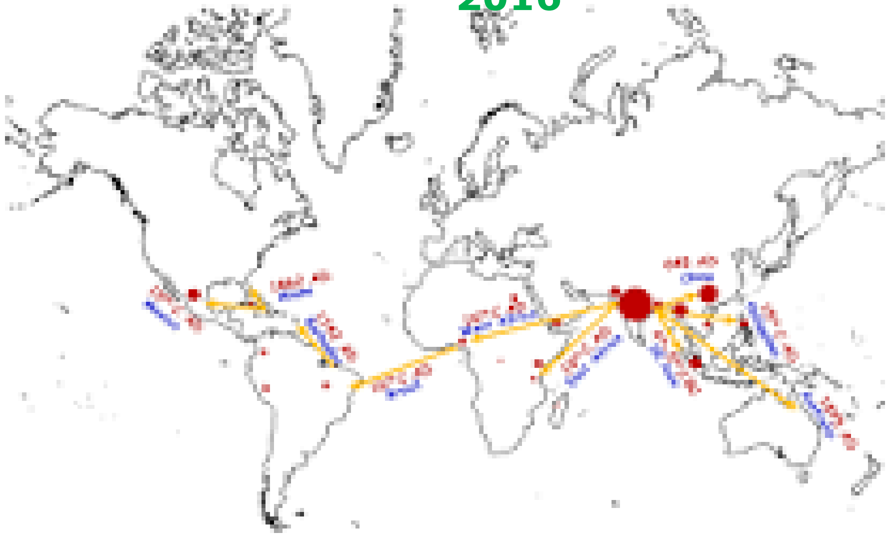
Mangosteen- *Garcinia mangostana*

Rambutan *Nephelium lappaceum*

- Lack of basic expertise in botany & taxonomy
  - Motivate younger researchers
  - Undertake skilling activities
- Poor representation of HCWR in collections
  - Increased efforts in exploring & collecting underutilized fruit & other horticultural plant species

- Difficulties in accessing & using geographic distribution- related species & related information
  - Improve exploration, mapping & haring
- Difficulties in identifying gaps in collections
  - Rectify taxonomic nomenclature
  - Analyse to identify areas/sites rich in TFT-WR for collecting
- Revise objectives of exploration & collecting
  - If collecting samples is not feasible then gather information useful to identify *in situ* conservation sites

Distribution of mango – Sing et al. 2016



Ex situ conservation

Ex situ conservation methods that can be used for HCWR include:

- Field genebank: Vegetatively propagated and/or perennial species
- Seed genebank: Species that produce orthodox seed
- Clonal repositories: Species that are maintained as clones – least genetic diversity
- *In vitro* genebank- Not exactly a conservation method
- Pollen bank: Mostly for use for the crossing of species/ varieties with asynchronous flowering
- Cryo bank: can be used for tissues, cell cultures, & orthodox seed for very long term conservation
- DNA bank: Not full-pledged technique yet, re-use limited, needs much research

(Note: Most of you may be familiar with *ex situ* methods)

In situ Conservation

TFTGR – being perennial species are candidates for conservation *in situ*

Challenges & Needs

Little has been done to date
- **Enhance actions & policy support**
- **improve research & training**

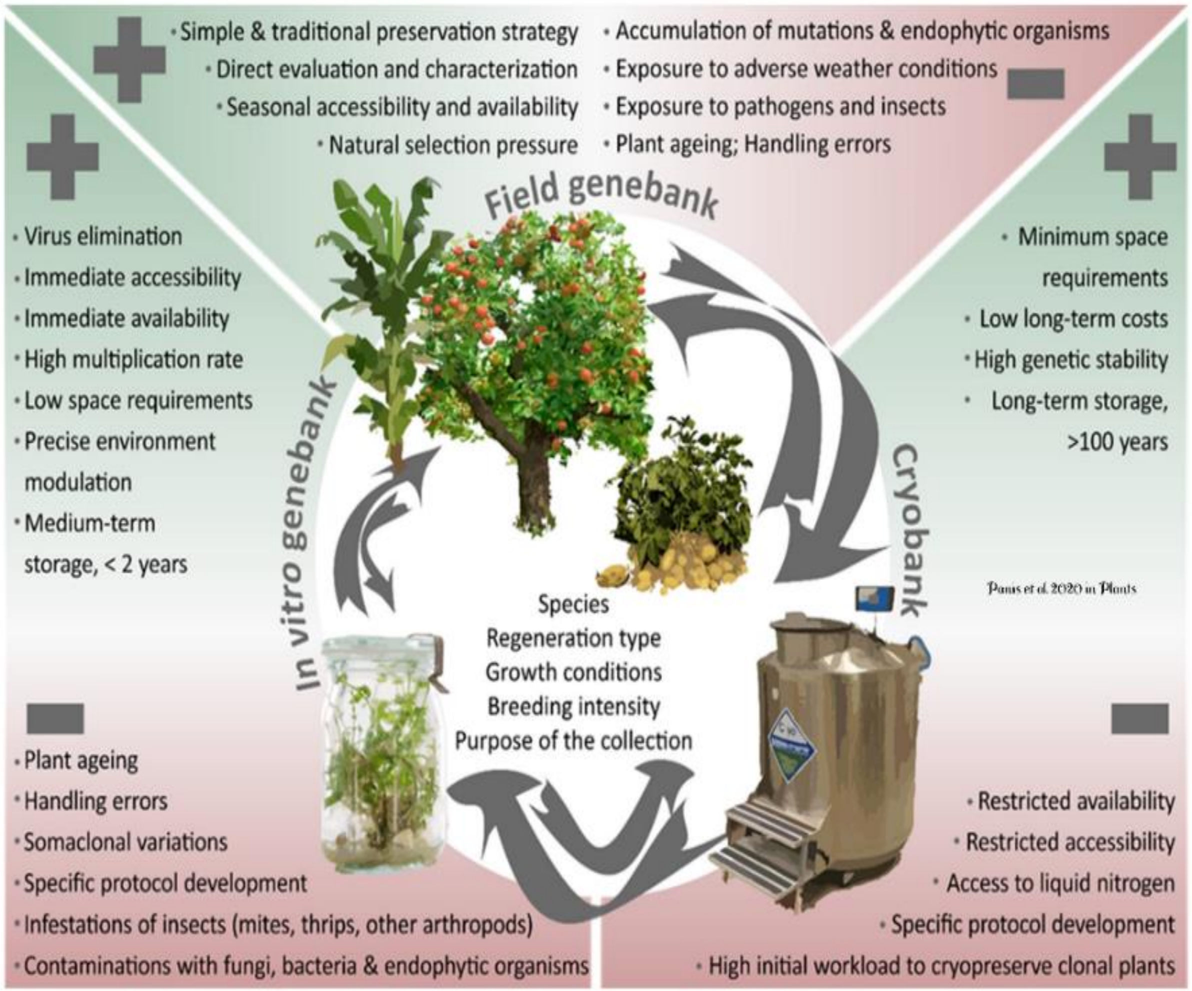
Close involvement of growers & communities
- **Internalize conservation actions with growers & forest dwellers' activities**
- **Train PGR staff in Participatory Methods to work with communities**

Understanding concerns of the people dependent on NTFPs
- **Understand local needs & local uses**
- **Avoid top-down-approach**

***In situ* conservation is not feasible in all situations**
- ***In situ* conservation is context-specific**
- **Integrate conservation of TFTGR conservation with PAs, reserves etc.**
- **Develop/modify forest management plans to include TFTGR**

Limited allocation of resources- financial & human
- **Demonstrate the feasibility & Importance**
- **Generate funds & approvals for optimal level of staffing**

Constraints to common to all types of conservation procedures



- **Lack of interactions between genebanks & users**
- **Difficulties in using modern tools for managing & using conserved germplasm**
  - **Integrate genotyping & sequencing into the genebank activities**
  - **Improve the effectiveness of documenting the genetic identity of accessions, tracking quantity & distribution needs, regeneration processes & timing, identification of duplicates & rationalization of collections etc.**
  - **Follow appropriate germplasm regeneration protocols are followed to maintain genetic diversity and/or genetic identity**

No single method can help to conserve all the genetic diversity

- **Use a complementary conservation strategy**
- **Make sure of duplicating collections**

Complementary Conservation Strategy

- We now know that there are 2 approaches to conservation - *ex situ* & *in situ*
- We also know, due to their limitations, no single approach can help us to conserve all the GD in a gene pool
- We need to understand that these two approaches are complementary in nature
- Conserving a gene pool should employ a combination of methods, from nature reserves to genebanks
- Provides a strategy that optimally conserves maximum diversity

Step 1: Networking of stakeholders at national regional or international levels.

▼

Step 2: Definition of objectives and sub-objectives.

▼

Step 3 Analysis of the feasibility of each option for each sub-objective in terms of infrastructure needs, costs and risks involved, etc.

▼

Step 4: Decision on conservation options for each objective/sub-objective.

▼

Step 5: Setting up enabling environment – policy/legal issues, funding.

▼

Step 6: Elaboration of the strategic action plan by stakeholders.

▼

Step 7: Implementation process

Dulloo, ME, Ramanatha Rao V & Engelmann, JMM. 2005. In Coconuts Genetic Resources (pp.75 - 90), PGRI

Utilization

http://www.fao.org/agriculture/crops/thematic-sitemap/theme/seeds-pgr/en/

The main driving force behind the efforts on conservation is the utilization

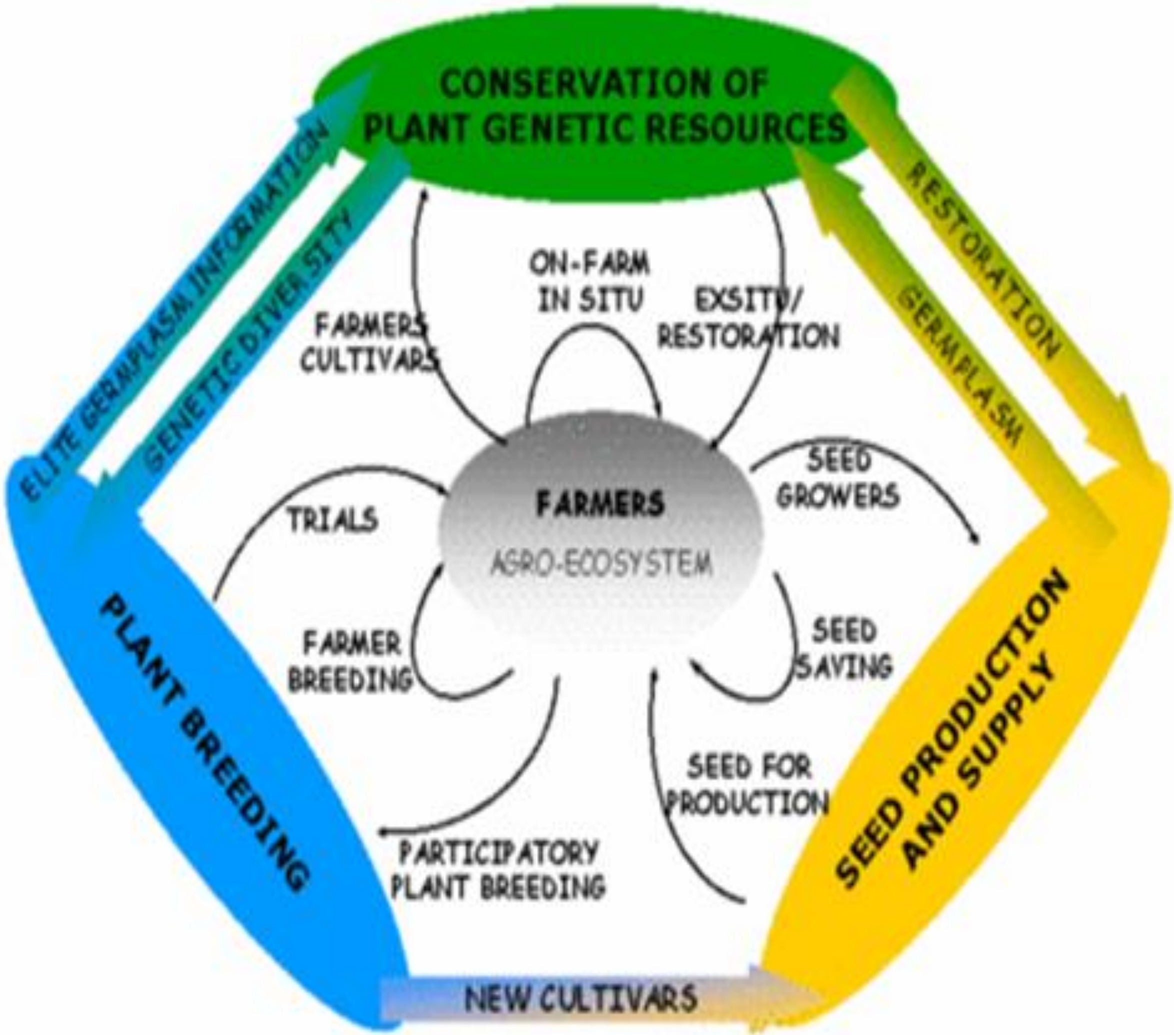
Use could be by

➔ Crop improvement by researchers

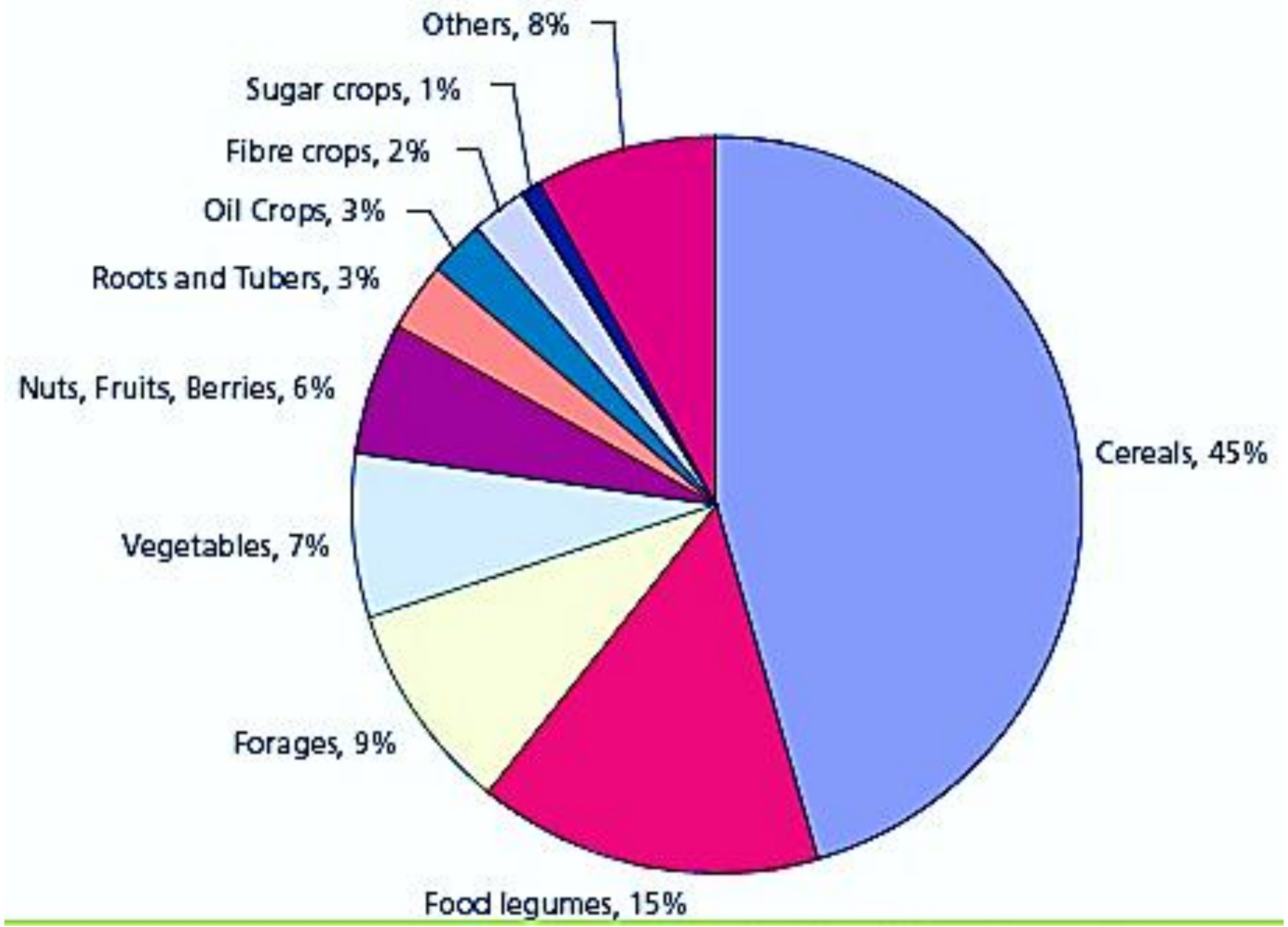
or

➔ Adaptation & sustainability needs of the farming community

- Collecting & conservation of PGR has made significant progress
- Effective use is still wanting



PGR Available for Crop Improvement



http://www.fao.org/agriculture/crops/thematic-sitemap/theme/seeds-pgr/en/

Global

- >7.4 million accessions
- >1750 genebanks
- 25-30% unique
- 10% wild crop relatives
- 11% in CGIAR Centre genebanks

Global Challenges in PGR Use

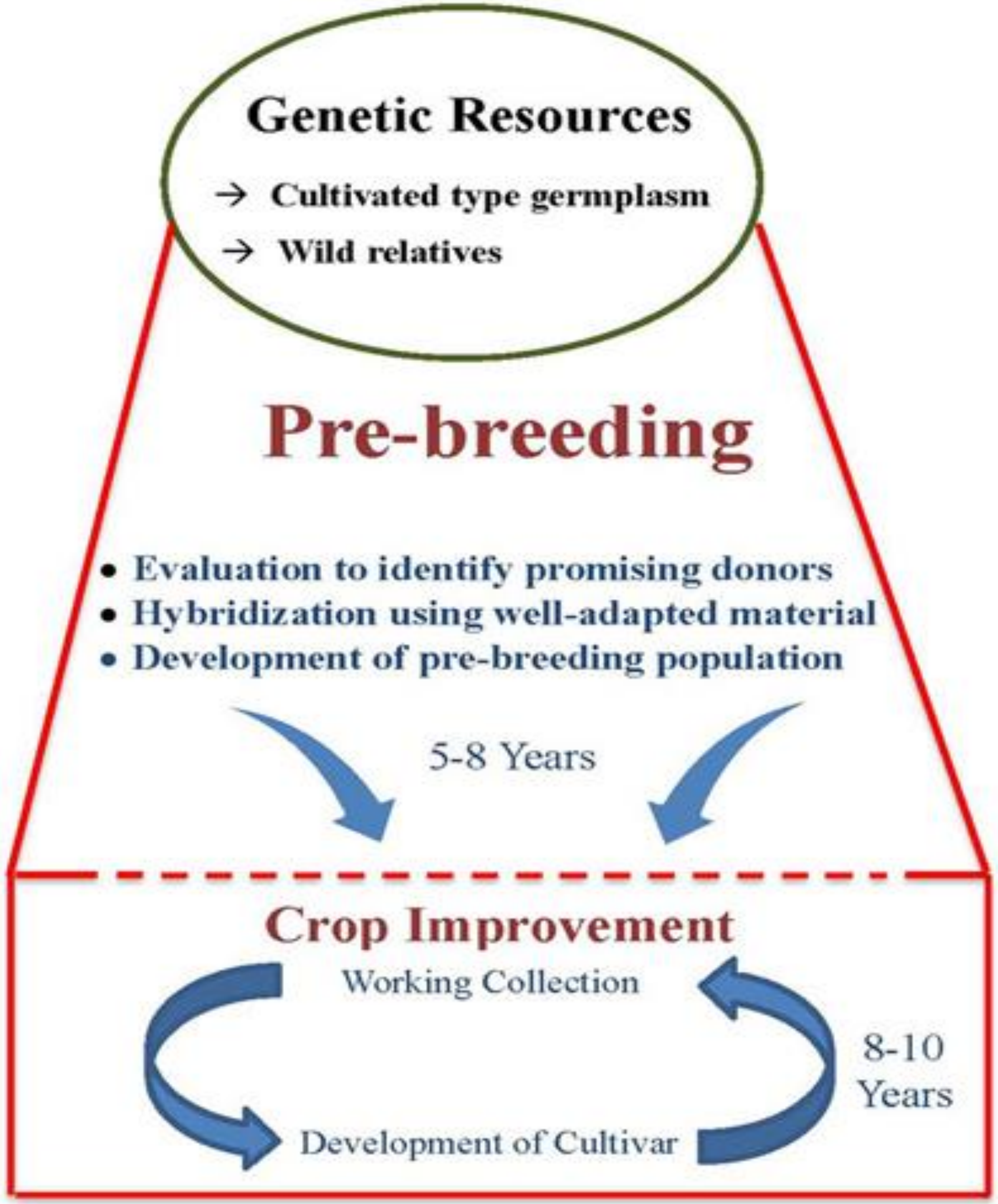
- ❑ Low use of germplasm (<1%) in most
- ❑ crops
- ❑ Most breeders use only working collections, as the size of the base col (e.g. Rice: >127,000 accessions)

In the case of TFTGR

- Consisting of mostly selected elite trees
- Some improved trait-specific trees/ clones

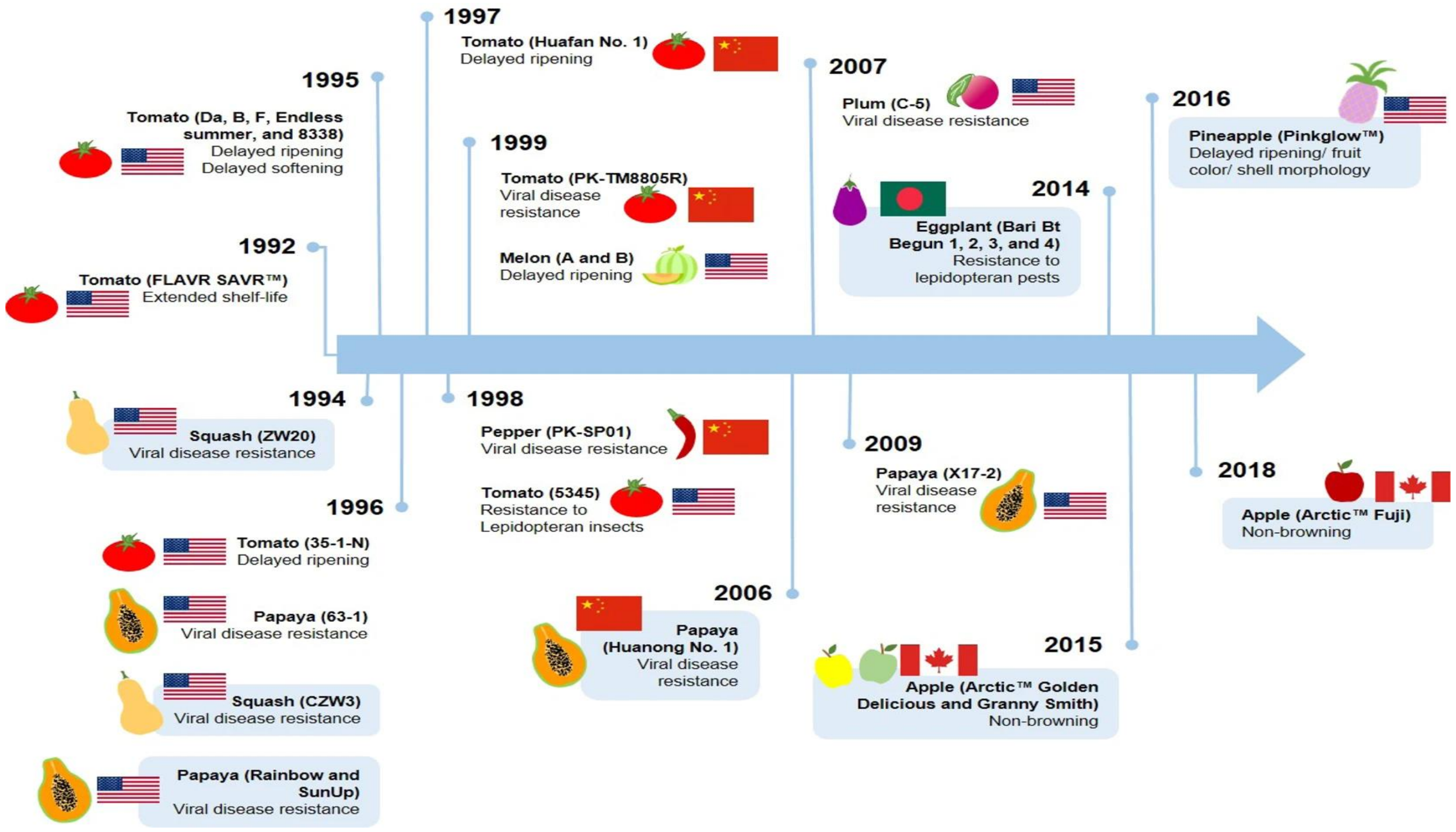
➔ Results in re-circulation of same germplasm

➔ The narrow genetic base of modern cultivars



Timeline of the development of fruit crops with engineered traits

From: Lobato-Gómez et al. 2021. Horticulture Research. 8: 166



Sustainable Production (SP)

SP – A concept based on intergenerational equity

➔However, all production practices consume resources

SP –an Aspirational Goal

➔ Needs continuous effort

To better appreciate the ecosystem services -ES provided by agriculture needs:

- ❑ **Development of appropriate econometric methods**
- ❑ **Special contribution of trees to ecosystem services**
- ❑ **Decision-support tools &**
- ❑ **Policy intervention strategies**

Agricultural biodiversity, especially the TFTs, helps significantly to ES

➔ Needs a better understanding of the ways in which Diversity can contribute to specific ES

http://www.mrsltd.com/sustainability.asp

Opportunities for Improvement Using PGR

Demands placed by climate change

Agriculture is a victim of climate change as well it is the means for mitigating

AGBDY -the biological basis of innovation & resilience

Proper ecosystem management & biodiversity provides several ecosystem services

➔ Resilient, productive, & sustainable systems, including

- ❑ Control of pests & disease
- ❑ Regulation of microclimate
- ❑ Decomposition of wastes
- ❑ Regulation of nutrient cycles, &
- ❑ Crop pollination, etc.

Opportunities:

- ❖ Re-introduction of landraces held in genebanks
- ❖ Varietal & crop diversification, varietal mixtures & mixed cropping
- ❖ Contribute to a reduction in input use for production
- ❖ Formal crop breeding must continue for adaptive traits
- ❖ Need to integrate modern knowledge with local/farmers' knowledge
- ❖ Risk mitigation &/or avoidance effects of varietal & crop diversification

Maintaining a high response diversity can facilitate post-disturbance recovery to compensate for the negative effects of CC

Food, Nutritional & Health Security (FNHS)

FNHS- Challenge to humankind – adequate and nutritious food available to all at all times

Need intensification of work UUC & wild foods can assist in attaining FNHS while sustaining PGR

Enhance incomes of rural poor so that they can afford nutritious food etc., through

- ✓ Focusing on new markets
- ✓ Value-added products at household & village levels
- ✓ Sale of agrobiodiversity-rich products

➔ Promote training & capacity development
➔ Institutionalization efforts
➔ Identify GR with traits for stability, ability to adapt, nutrition etc.
➔ Develop varieties with higher productivity with broad/specific adaptations
➔ Gradually move towards conservation agriculture (= sustainable agriculture)

For sustainable production (almost) & FNHS secure future

Utilization is the main driver for most PGR conservation efforts

- However, conservation TFTGR, especially *in situ*, goes beyond just using for improving crops
- They should become integral to larger conservation efforts: i.e., conservation of biodiversity &/or environment
- Using TFTGR requires efforts on pre-breeding/germplasm enhancement (maybe be dispensed with if modern methods come into use)
- Needs cost-effective long-term conservation methods – System Approach
- Use of modern scientific methods & tools instead of arbitrary identification & delineation *in situ* conservation sites
- Needs increased research on population genetics, molecular mapping and the impact of climate change, and policy studies
- Many TFT species found in the wild require different approaches & close interaction with communities that exploit these resources for their livelihoods

Climate Change and Biodiversity Loss

Urgency due to CC and rapid loss of biodiversity have placed new demands

Understanding of changes that are happening

Developing & implementing adaptation & mitigation strategies

Climate change will cause

- ➔ **Shifts in the distribution of areas suitable for the cultivation of a wide range of crops, including horticultural species.**
- ➔ **Studies indicate the loss of cropping areas in several parts of the world, including India**
- ➔ **Although farmers usually adapt well, as the changes will be rapid and complex, will need assistance in adapting to changed conditions**
- ➔ **CC can create favourable conditions for invasive alien species, pests and parasites threatening not just food production, but to local plant species**
- ➔ **Threatens the survival of the strategic reservoir of crop and livestock genetic resources needed to adapt production systems to future challenges**
- ➔ **Diverse genetic resources, including horticultural, can play an important role**

Credit: The Hindu

For example, climate change might

(1) Decrease chilling and inhibit bloom and fruit set in horticultural crops,
(2) lead to high temperature and wind during bloom or ripening that could negatively impact fruit set or fruit quality,
(3) Increase evapotranspiration rates that could lead to water deficits, and
(4) Increase problems with heat stress

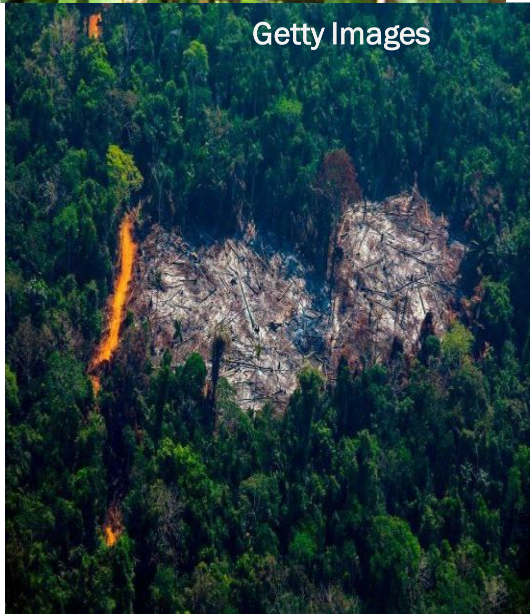
CWR contain several genes of potential value for plant breeding

➔ Among these are many traits that are relevant for climate change adaptation

Need to evaluate TFTGR to identify to develop

➔ New cultivars tolerant to high temperature
➔ Resistant to pests and diseases, some of which may be new
➔ Short in duration
➔ Produce good yield under stress conditions
➔ Adopt hi-tech horticulture

Some of these are currently on, but on a small scale
'Business as usual' is not going to help
Needs rapid & drastic shift in our strategies & scale of implementation



Human Dimension

- Probably the most important aspect of any conservation effort
- Conservation & use depends on felt needs, understanding & attitude of people that are dependent & involved
- Do not ignore the needs of farmers & consumers

Human elements include:

People in general

- Improved understanding that the farming community & consumers of agricultural products need to benefit
- All efforts are sustainable should & are amenable to changes that may have to be made as technologies change over time, i.e. not static

Scientific & technical

- Need competent scientists & managers
- Need to be in tune with the basic philosophy of conservation -for use in the present & future generations
- Not averse to filed work
- Be able to relate to & work closely with farmers & indigenous communities

Policymakers

- Awareness of the role & significance of TFTGR conservation & use in sustainable horticultural conservation, production & reduction of poverty
- Policy support for conservation efforts, along with the requisite funds

Collaboration among all actors

- Networking & collaborating with each other that transcends individual or institutional interests & barriers & even nations
- Multi-disciplinary, multi-institutional and multi-sectoral cooperation (3M approach) PLUS Regional & International collaboration

Concluding Remarks

- **Interdependency: No country is self-sufficient**
- **Need to develop strategies for conservation of HGR - fully support, participate & implement the conventions, treaties & agreements that aim to effectively conserve & sustainably use**
- **South, SE Asia & South America are rich in TFT wild relatives, however, their economic value, value as genetic resources, a means of livelihood & associated cultural values are seldom demonstrated**
- **Multidimensional problems: Resolution of problems surrounding conservation & use of TFTGR requires the attention of all stakeholders**
- **Issues that need to be addressed are:**
  - **Collecting & Exploration**
  - ***In situ*/on-farm conservation**
  - **Evaluation and & utilization**
  - **Change in the mindset of people involved**

➔ **Above all, sustainability needs to be central to all endeavours**

CONSULTING SERVICES

Thank you for your attention