Challenges and Prospects for Future Plant Breeders

CL Laxmipathi Gowda*

Former Deputy Director General (ICRISAT) &

Co-Founder, GRSV Consulting Services

Mysuru, Karnataka

(*with inputs from MJ Vasudeva Rao, Sharan Angadi and V Ramanatha Rao)

Plant Breeders: The Unsung Heroes

- **Plant breeders are unsung heroes, and rarely recognized**
- **They don’t write papers for High Impact Journals and find it difficult to get Fellowships of Science Academies.**
- **Plant breeding has lifted billions of people out of hunger and poverty**
- **Current challenge is to increase food production due to bourgeoning population, and effects of climate change**
- **Breeders anticipate future needs of farmers and consumers and prioritize breeding efforts to meet those needs**
- **Plant breeder is now being asked to deliver results more urgently than at any time previously, due to challenges posed by climate change**

What is plant breeding?

- **Plant breeding refers to basket of technologies to create new and improved plant varieties with desired traits**
- **Accelerated and targeted evolution directed by Man**
- **Application of principles of genetics to crop improvement**
- **Systematic procedures used to improve trait phenotypes by crossing and selection, directed manipulation of the genotype at the DNA level, and introduction of new desired genes to improve varieties**
- **Plant breeding is both *Science* and also an *Art* of selecting desired plant types (with good eyes: visual evaluation)**

What plant breeding can do over centuries

NATURAL "CORN", 7000 B.C.

PEEL IT BY HAMMERING REPEATEDLY WITH A HARD OBJECT

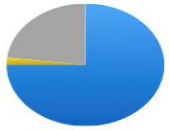
TASTES LIKE VERY DRY, RAW POTATO

19 MM

5-10 VERY HARD KERNELS

8 KNOWN VARIETIES

ONLY FOUND IN CENTRAL AMERICA



75.0% WATER

1.9% SUGARS

23.1% OTHER
MOSTLY STARCH

ARTIFICIAL CORN, 2014

STEAM COOKS IN MINUTES

Sweet, refreshing and juicy

AVAILABLE IN FIVE COLOURS:

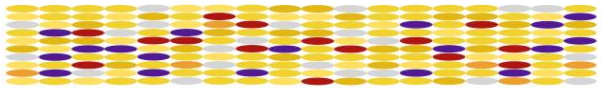
- WHITE
- YELLOW
- DARK RED
- DEEP PURPLE
- BLUE-BLACK

190 MM

~1000 Times Larger

EASY TO PEEL

No Hammer Required!

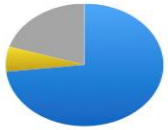


~200 VARIETIES

67-Fold Increase

Annual Production: 790 Million Tonnes

Grown in 69 Countries



73.2% WATER
2% Less Juicy

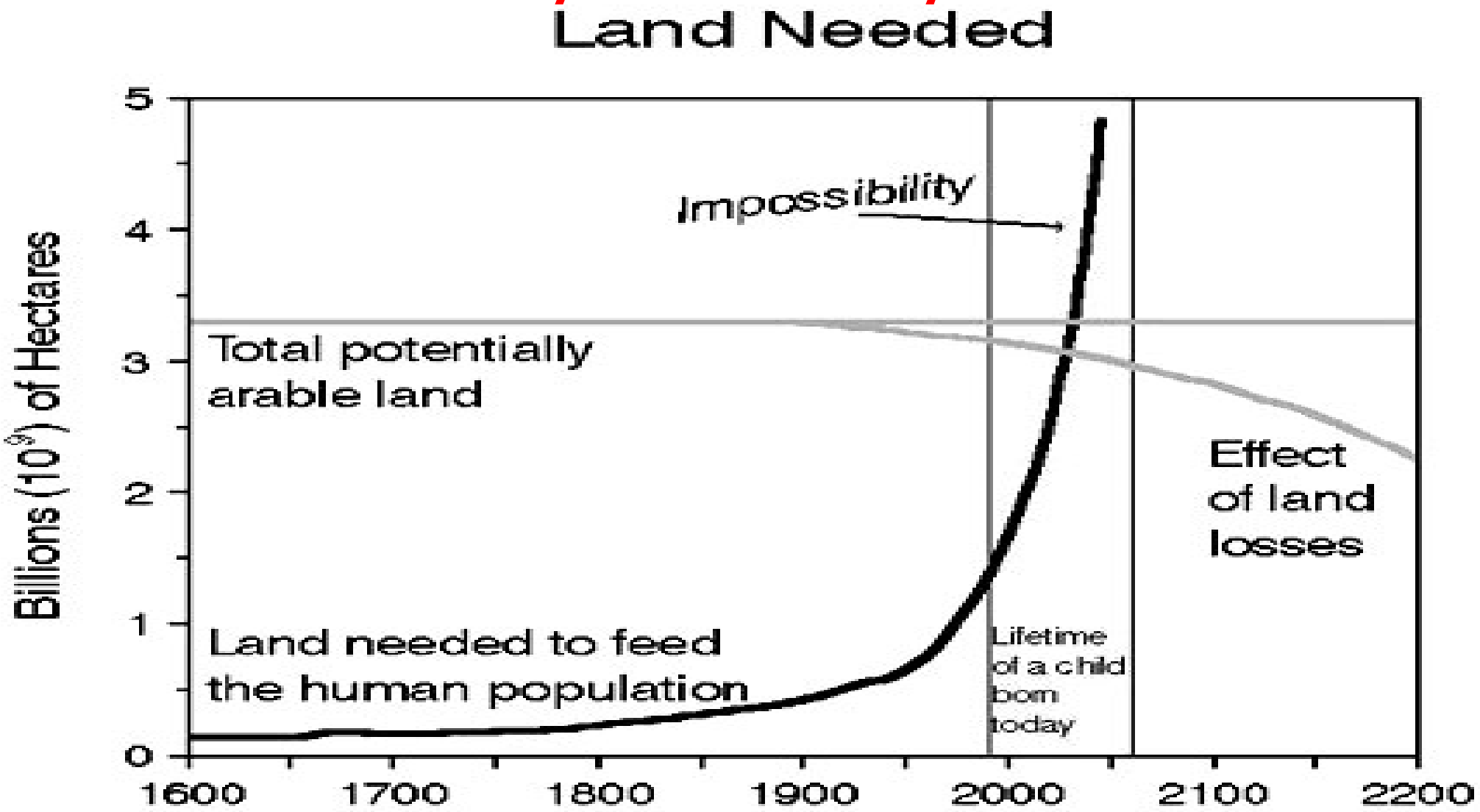
6.6% SUGARS
3.5x Sweeter

20.2% OTHER
Still Rich in Starch!

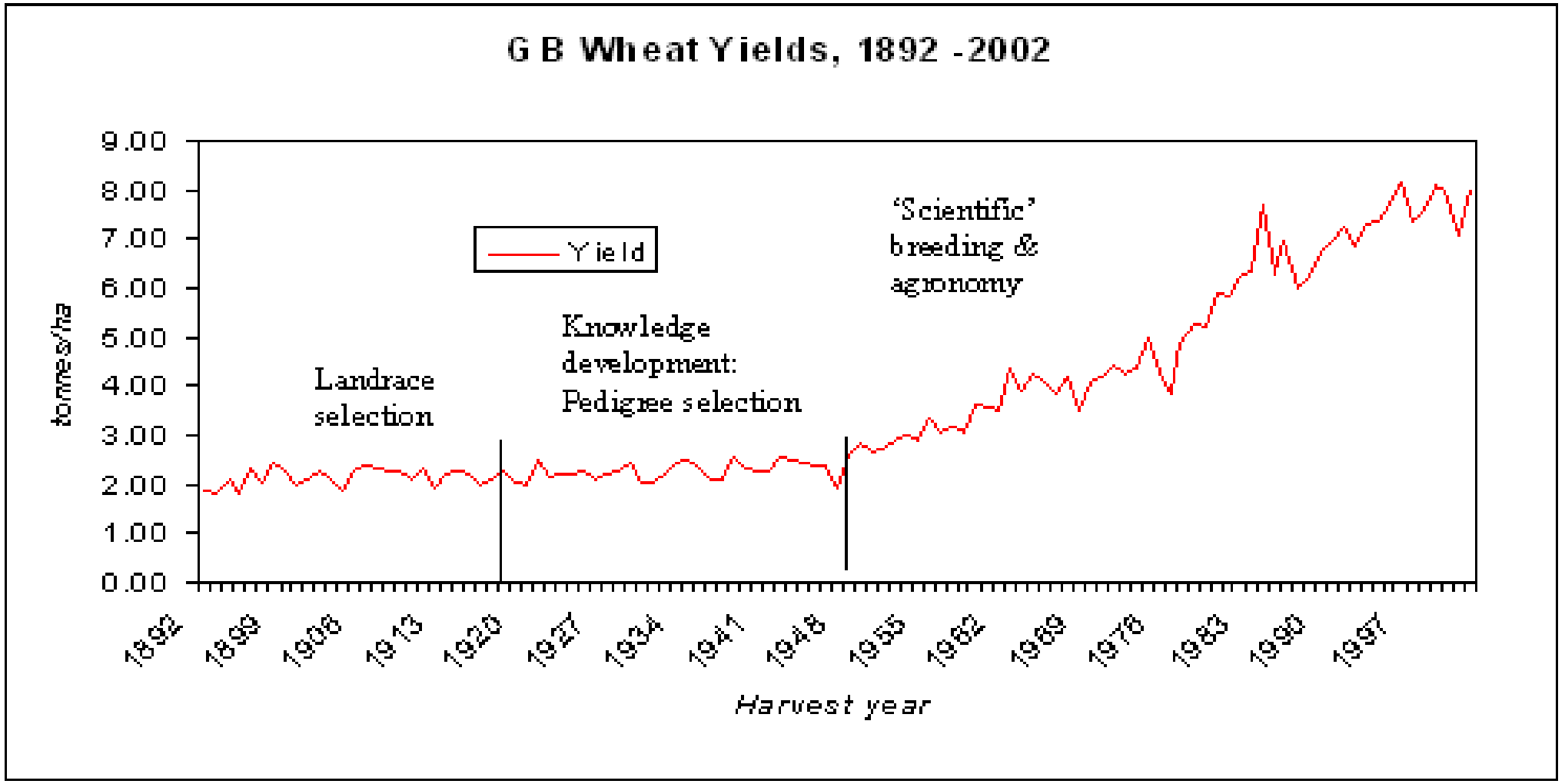
Contributions of plant breeding

- **Carrots, beetroot, and other vegetable and fruits we eat today are result of thousands of years of selection/ breeding by generations of farmers**
- ***Wild cabbage* –carefully selected over centuries has given us kale, broccoli, Brussels sprouts, cauliflower, cabbage and turnips**
- **Plant breeding has been responsible for >50% of the gains in yield**
- **Although there are criticisms of the Green Revolution, it is widely acknowledged that it has helped saved millions of lives through improved high-yielding varieties.**
- **We are now facing a similar challenge for increasing food production because of burgeoning population, changing diet and food habits, and a changing climate**

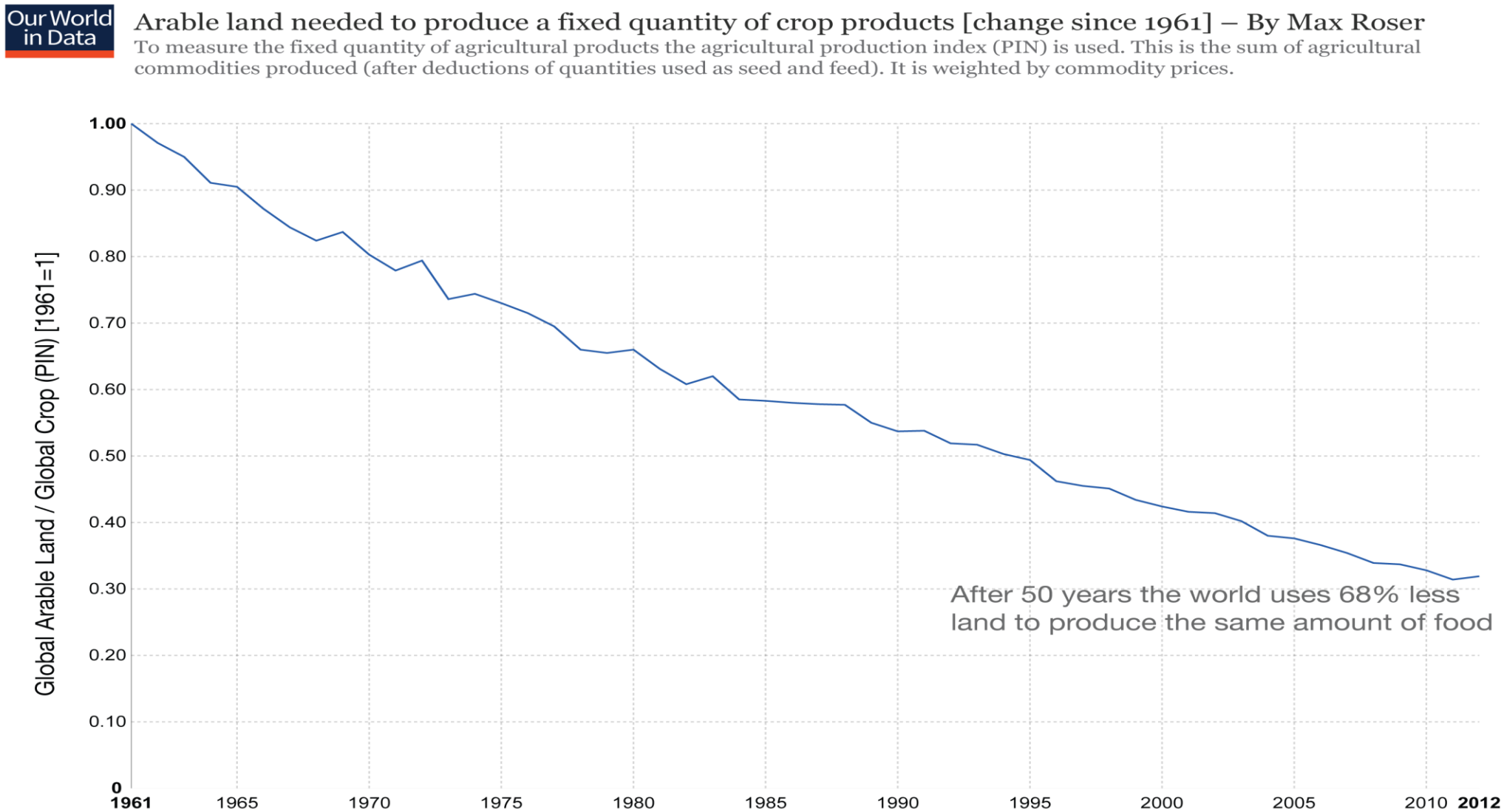
Global availability of Land by 2200



Impacts of breeding on Wheat Yields



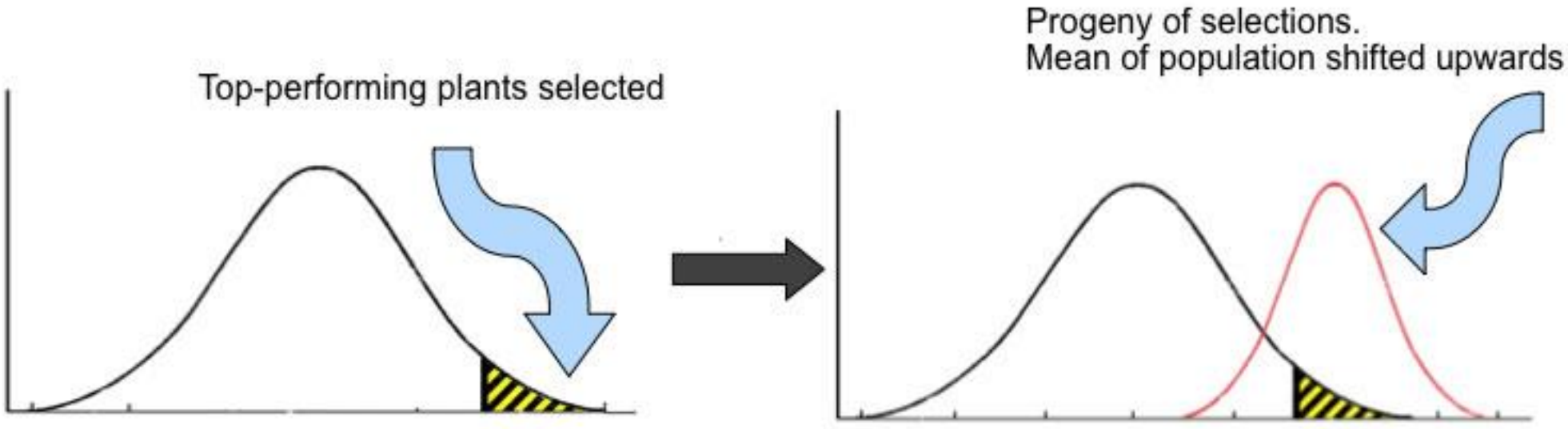
Use Less Land Now to Produce More Food



Major activities in Plant Breeding

- **Identify problem and define objective of a breeding program**
- **Accessing germplasm with desired traits/variation**
- **Creation of new genetic variation–Hybridization, Polyploidy, Mutation, and Genetic Engineering**
- **Selection—identify and isolate superior plants with desirable trait combinations**
- **Evaluation of selected progenies in replicated, multi-location/ multi-season field trials, as required**
- **Identification and/ or release of varieties/ hybrids**
- **Production of quality seed of selected promising varieties/ hybrids**
- **Supply of quality seed to farmers at an affordable price**

Basic principle of selection over generations



Classical and traditional plant breeding tools

Hybridization and Selection

Wide crossing

Chromosome doubling & Polyploidy

Male sterility

Mutagenesis

Tissue culture

Haploidy and Di-haploids

In situ hybridization

DNA markers

Advanced technologies for plant breeding

- Molecular markers-assisted selection
- DNA sequencing
- Plant genomic analysis
- Genomic selection
- Bioinformatics
- Microarray analysis
- Genetic transformation
- Gene Editing Technologies

The success of plant breeding (PB)

- **Increases in yield are derived both from improved varieties and from improved crop husbandry (agronomy).**
- **In vegetable crops, research suggests about a 50-50 split between genetic gain and gain attributed to management.**
- **Genetic gain in grain yield of 75 Kg ha^{-1} yr^{-1} for corn can be attributed to breeding.**
  - **2.5 ton/ha increase in yield every 30 years.**
  - **Maize yields have increased 60% to 120% in the U.S. since 1940 (Cooper et al., 2004. Genomics, Genetics, and Plant Breeding: A Private Sector Perspective. Crop Science. 44:1907-1913).**
- **"Green revolution" varieties have increased yields 2 to 3 fold in many "developing" nations (Knight, 2003).**

Current gaps in Plant Breeding-1

- **Recognizing the basics of PB—Introduction, Hybridization, Selection**
- **Understand that PB is to ensure value gains to meet changes in the environment:**
  - **Climate, IPRs, NBA, Regulatory Mechanisms, Dietary changes, etc.**
- **Knowledge of agronomy, physiology, pathology, entomology, etc.**
- **Excessive emphasis on theory and less on practical training, including field selection and tests**
- **Lack of mentors/ guides for young breeders (similar to Gurukul system)**
- **Breeders not visiting fields and 'talking to plants' for selection**
- **Limited experience of seed production and distribution system**

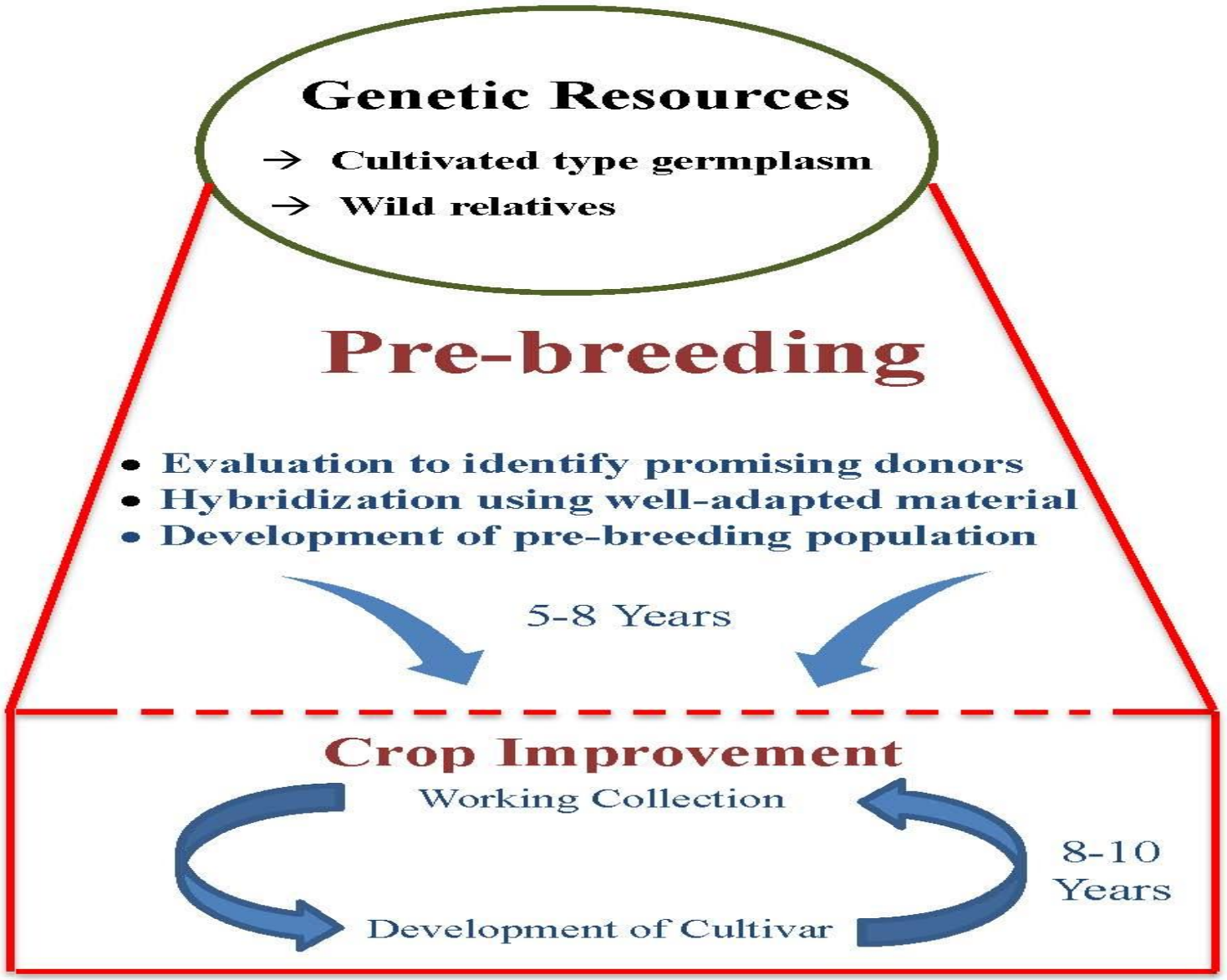
Current gaps in Plant Breeding-2

- **Paucity of “hands-on experience” in nursery management, emasculation, pollination, field selection, harvest and threshing, and post-harvest selection**
- **Lack of knowledge in quantitative and population genetics, biometrics, and related fields**
- **Conventional breeders not using new breeding tools (NBTs); and so-called Molecular Breeders not knowing Conventional Breeding**
- **While NBTs are precise, fast and efficient, they are not panacea**
- **Lack of rigor in data collection, analysis and interpretation**
- **Recognition that field evaluation is essential for final selection**

Enhanced use of Germplasm in Breeding

- **Diversity available to breeders is getting reduced**
- **Enhanced Germplasm use will strengthen plant breeding through:**
  - **increase in efforts to phenotype and genotype germplasm accessions using standardized methods;**
  - **enhanced information sharing via the Genetic Resources Information Network (GRIN) and its inter-operability;**
  - **increased attention to pre-breeding activities;**
  - **improved training opportunities in practices for incorporating germplasm in breeding programs;**
  - **expanded outreach efforts to strengthen public support for breeding, and partnership with private sector**

Pre-breeding: a link between germplasm conservation and utilization



Recent advances in plant breeding-1

- **Speed breeding or fast track breeding technologies can help in developing and testing of new cultivars in the shortest time**
- **NextGen technologies and big-data analytics should help the speed and efficacy of breeding programs**
- **Genomic selection or genome-wide selection (GS) has been highlighted as a new approach for marker-assisted selection (MAS) in recent years**
- **The Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) technology has been succesfully applied in gene editing**

Recent advances in plant breeding-2

- **Remote sensing techniques have improved high-throughput plant phenotyping.**
- **Light detection and ranging (LIDAR) provides a powerful new tool for 3D phenotyping with the rapid development of facilities and algorithms**
- **Capacity to monitor gene expression at the molecular level, and so unravel/control the G × E interactions that limited their benefits**
- **There is enormous interest of private companies in using new breeding techniques (NBTs) for a wide range of crop species and traits**

Designing Graduate-level Plant Breeding (PB) Curriculum (Millers et al. 2011)

- **Knowledge of traditional plant breeding, statistics, experimental design, along with genomics and biometrics and other NBTs.**
- **Essential experiences are: designing experiments, field and laboratory data analysis**
- **Experience in communications, teamwork, and management**
- **Experience in judgement and ideas, time and efficiency in completing tasks**
- **Reforming PB education to be dynamic to include emerging technologies from life sciences and plant breeding**
- **Integrate needs of public and private sectors to PB curriculum**

Private Sector Role in Training Plant Breeders

- **Contemporary breeding curriculum should include hands-on experience with selection of complex traits in actual plant populations, and basic biology and genetics of plants**
- **Plant breeding education should also comprise several professional skills, including business management, and intellectual property rights.**
- **The private sector should play an increased role in the plant breeding.**
- **There is a need for alternative types of training in plant breeding geared towards working breeders and new breeders (Internships).**
- **Private companies should use new breeding techniques (NBTs) for a wide range of traits and crop species.**

The Future & Way Forward-1

- Improve the Plant Breeding (PB) curriculum, with basic Plant Breeding, Crop Management (Agronomy), etc.
- Resurrect Conventional Breeding by integrating with NBTs (molecular markers, gene editing, etc.)
- Recognize that Plant Breeding is a Teamwork:
  - breeder, pathologist, entomologist, physiologist, bioinformatics, genomics, etc.
- Build on strength of current NBTs, but still grounded to the conventional breeding and proper field evaluations
- Breeder should know how to use resources (financial, land, labor, etc.) effectively and efficiently
- Genes from diverse species, genera and genes across plants and animals likely to be used in future

The Future & Way Forward-2

- **Adopt high-throughput phenotyping approaches, with rigor in data collection and analysis, for proper interpretation and use**
- **Use Open-access sources such as IBP (Integrated Breeding Platform) and GOBII (Global Open-access Breeding Informatics Initiative) effectively to reduce costs and increase efficiency**
- **Seed Industry mentorship and Internship program for Undergraduate and Post Graduate students**
- **Avoid duplication of research and reinventing the wheel, especially in Universities and Research Institutes**
- **Establish “Centralized Labs for Genomics and Bioinformatics” to reduce costs and increase breeding efficiency**
- **Finally, Breeders MUST visit the fields daily, to be effective and efficient**


Thanks for your attention