



# *Application of Molecular Breeding for Product Development*



Bayer Russia Molecular  
Marker Training

24 July 2023



# Bayer Russia Molecular Marker Training: Application of Molecular Breeding for Product Development



- 1 Business justification for molecular breeding**
- 2 R&D and connection with Product Development Pipelines**
- 3 Developing genomics pipelines and processes**
- 4 Bayer's insight into workflows across crops**

# Plant breeding: Improving genetics and product offerings

- // **Crop resiliency** to guard against damage from pests, disease and a changing climate
- // **Quality improvement** to meet the needs of the food value chain and consumers
- // **Enhanced nutrition** to benefit society

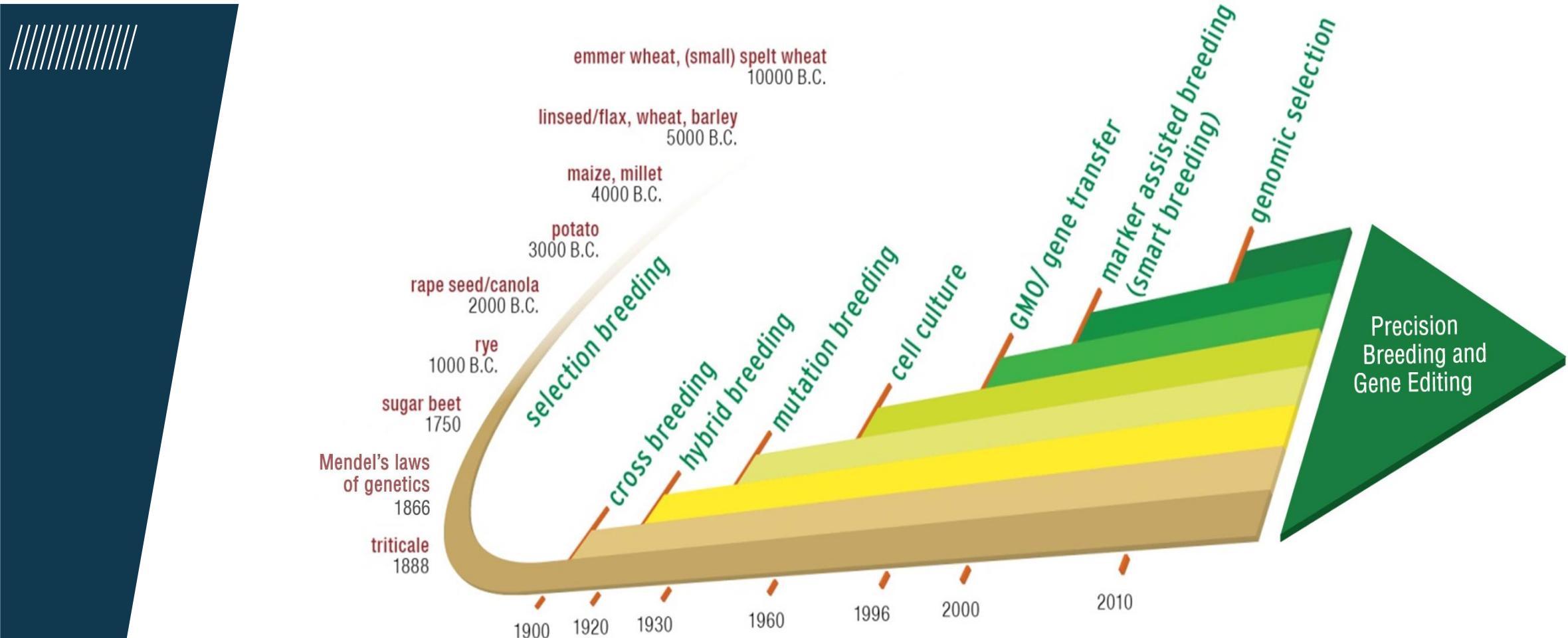
*Plant breeding innovations strive to benefit farmers and consumers while using fewer natural resources*



# WE'RE EXCITED TO BE A PART OF WHAT'S NEXT FOR AGRICULTURE



Today, plant breeders are constantly **developing improved crops** through new breeding techniques, just as they always have.



# Our Breeding Process

Selecting the best quality products that deliver value to our growers

8-10 YRS



1 Select Parents

2 Make a cross

3 Plant the F1 seed

4 Inbreed multiple generations to make pure lines or use DH

5 Make selections

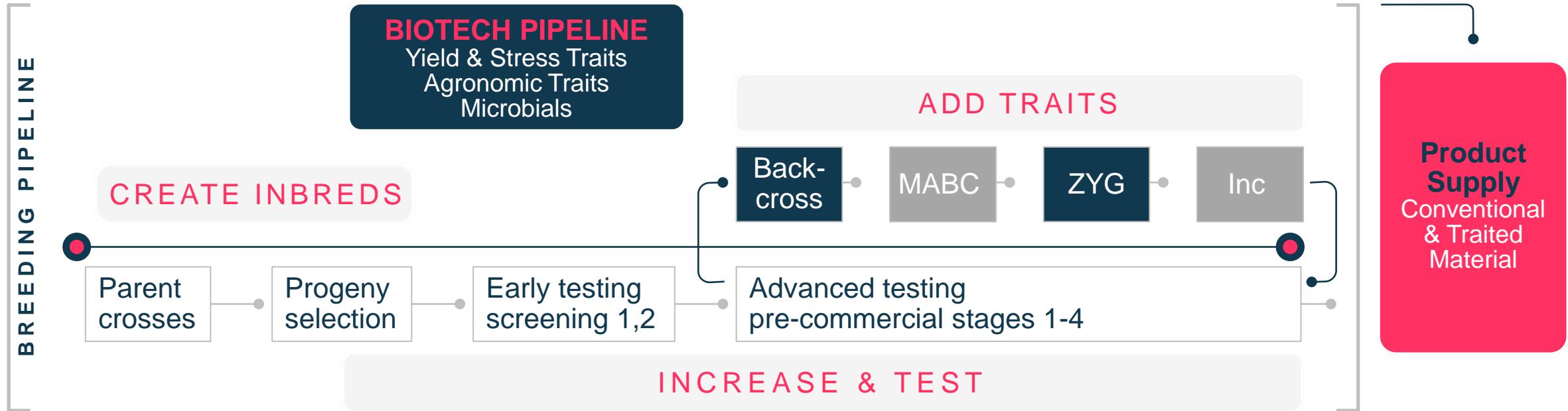
6 Evaluate in target region and Selection

7 Recycle the best parents

8 Release a new product



# Breeding product pipeline overview



## GLOSSARY

**MABC**  
Marker Assisted Back Cross

**ZYG**  
Zygosity

**Inc**  
Seed Increase





Product design and development

# NEW SOLUTIONS FOR FARMERS



## BREEDING

**1,000,000's**  
of possible candidates



## TRAIT INTEGRATION

**1,000's**  
of possible candidates



## PRODUCT SUPPLY

**100's**  
of candidates



## FIELD SCALE TRIALS

**10's**  
of candidates



## COMMERCIALIZATION

**1-3**  
candidates



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## Breeding 1.0



Bigger & Faster  
1996 - 2006

## Breeding 2.0



Increased Accuracy  
2006 - 2013

## Breeding 3.0



Digitally Enabled  
2013 - 2019



Customer Designed  
2019 - 2025+

**Breeding plays** a critical role in creating the next generation of customer solutions and Precision Breeding is our path forward

Building this off almost **25 years** of constant innovation and passionate execution



# From selecting the best to **designing the best** **in Precision Breeding**

*In one of the most transformational shifts in breeding history, Bayer's Precision Breeding future will drive tailored solutions that reflect the specific needs of our customer farms, crops, soils and agronomic practices.*

- // Intimately **understand market needs** to design products that address unique large and **small customer needs**
- // More **environmental data** on **product performance**
- // Ability to start **developing more climate smart products**



# Teams identified **six** core Precision Breeding technical outcomes



**Accelerate** product development, **improve** operational effectiveness, and **enable** tailored solutions





*Aligned outcomes across crops and regions*

# Product Design core strategies



## Agile Product Delivery

Executing the product concepts and delivering to downstream partners aligned to Bayer's global Seeds & Traits portfolio



## Genome Design @ Scale

Data-driven prescription of genome design targets for editing and breeding so product concepts are integrated at the front end of the breeding pipeline



## Quantitative Genetics Framework

Globally connected framework that leverages genomic data to determine the optimal course of action across stages, pipelines and correlated environments



## Prescriptive Data Collection

Leveraging powerful genomic prediction models and phenotypic data collection to predict performance of individuals in all environments and accelerate line delivery to Product Development



## Continuous Cycle

A platform for continued innovation that shortens cycle time for genetic gain and provides immediate deployment path for innovation

# Evolving from selecting the best to designing the best

What we can learn from seed chipping, markers, genetic mapping and predictive analytics

// Proprietary seed chipping technology enables breeder to **know every seed**



// Latest marker-assisted breeding, genetic mapping and predictive analytics fuel an **increase in the number of products screened early in the breeding process**



// Researchers can make faster decisions to pinpoint which products are best **for testing in local fields**



// Powered by data analytics, breeders can make more informed **selections earlier in the pipeline** to enable **longer field testing before commercialization**



**Seed Chipper**



A sample of DNA from a seed chip is sequenced and analyzed

**Sequencing Machine**



**Millions of data records are analyzed** nightly from our breeding database, accelerating our research pipeline. The use of molecular markers identifies key genes in combating diseases.



A 2x2 inch gene sequencing chip holds the equivalent of 14 acres of information

# Genotyping Technology Comparison

~10k to ~800k  
markers

## High density markers

HD-Array by Affymetrics or Infinum. Selected markers which are best fit for the breeding pool as [Fingerprinting \(FP\)](#) platform. Used on parental / elite germplasm in later breeding pipeline.

## Medium density markers

[Genotyping by sequencing \(GBS\)](#), pre-designed marker set based on FP. Used on progeny of the breeding populations and imputed to FP level for genomic prediction. Can also be used in TI / Discovery.

## Low density markers

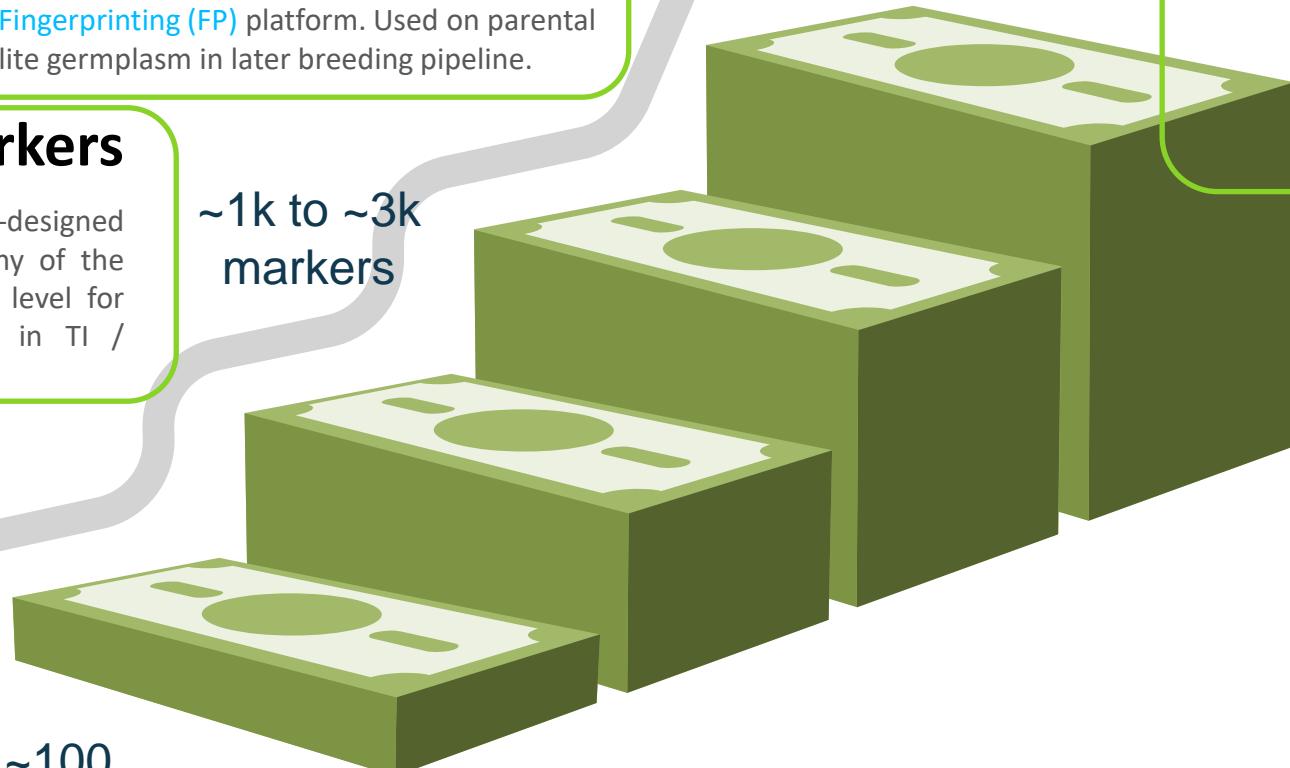
Taqman / KASP markers. Used to track traits controlled by limited number of genes.

1 to ~100  
markers

~1k to ~3k  
markers

## Genomic sequence

Elite / core / founder germplasm to identify necessary polymorphisms to strengthen the genomics platform and additional coverage to support traits discovery.



# Genetic testing is critical to ensure quality for the commercial product

*Low density genotyping applications in Product Supply*

## Varietal and Trait Purity

Uses low density genotyping to determine purity



## Hybridity & Identity

Uses low density genotyping to confirm cross-pollination and correct parent usage



## Adventitious Presence

Uses low density genotyping to ensure no unintended Biotech trait is present

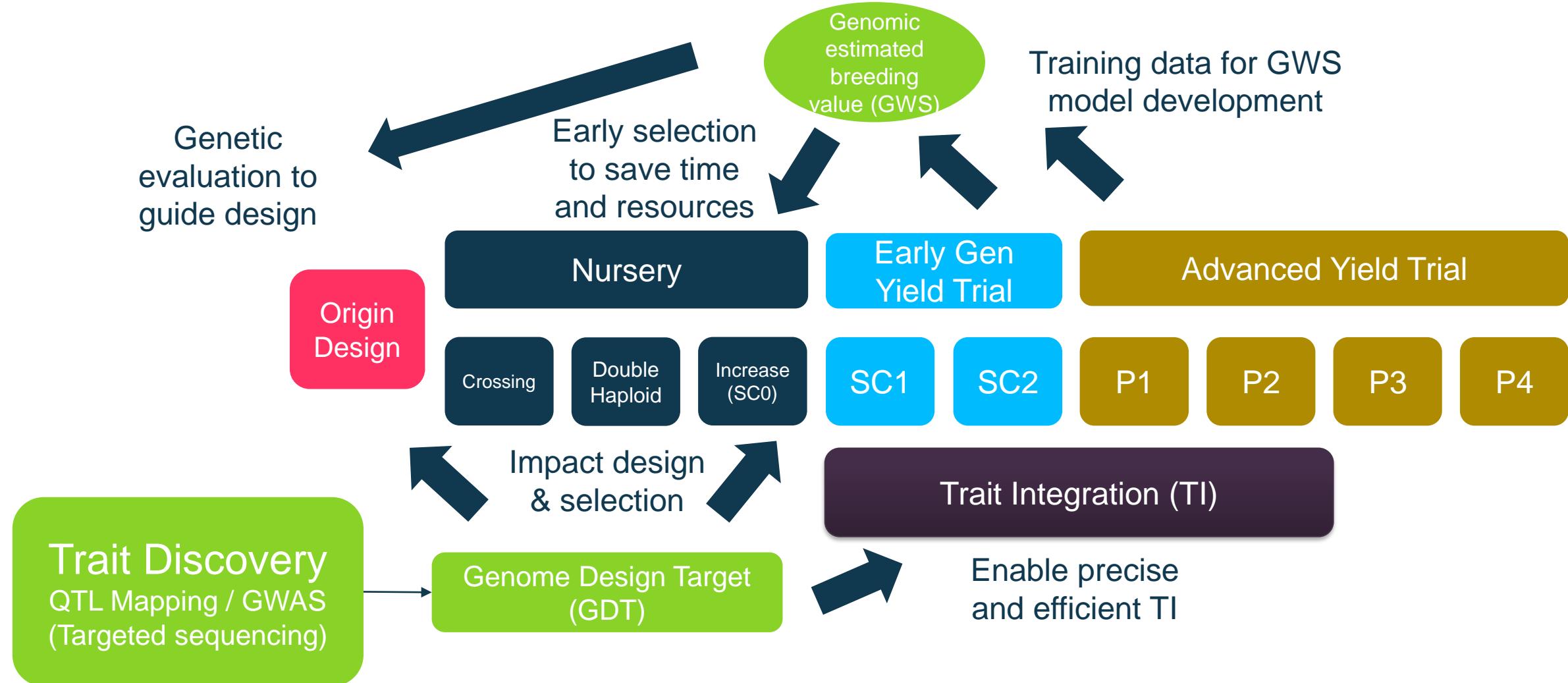
## Sterility

Uses low density genotyping to confirm sterility in expected inbred lines

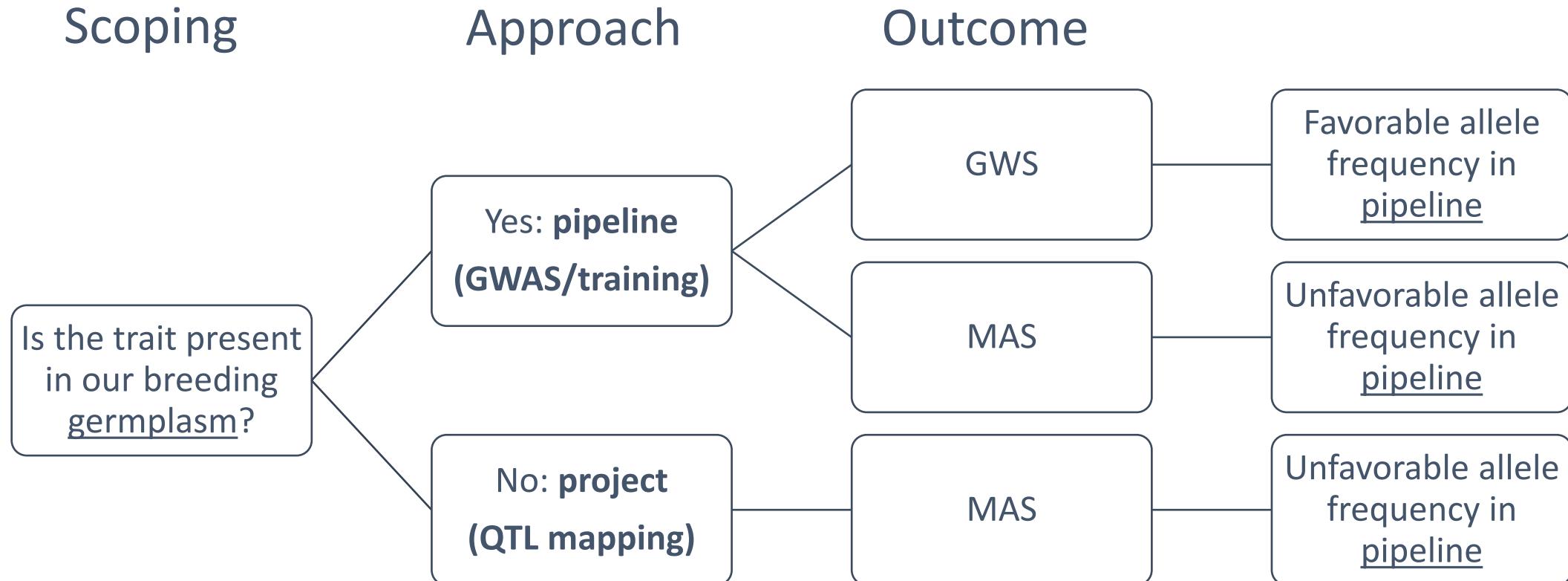
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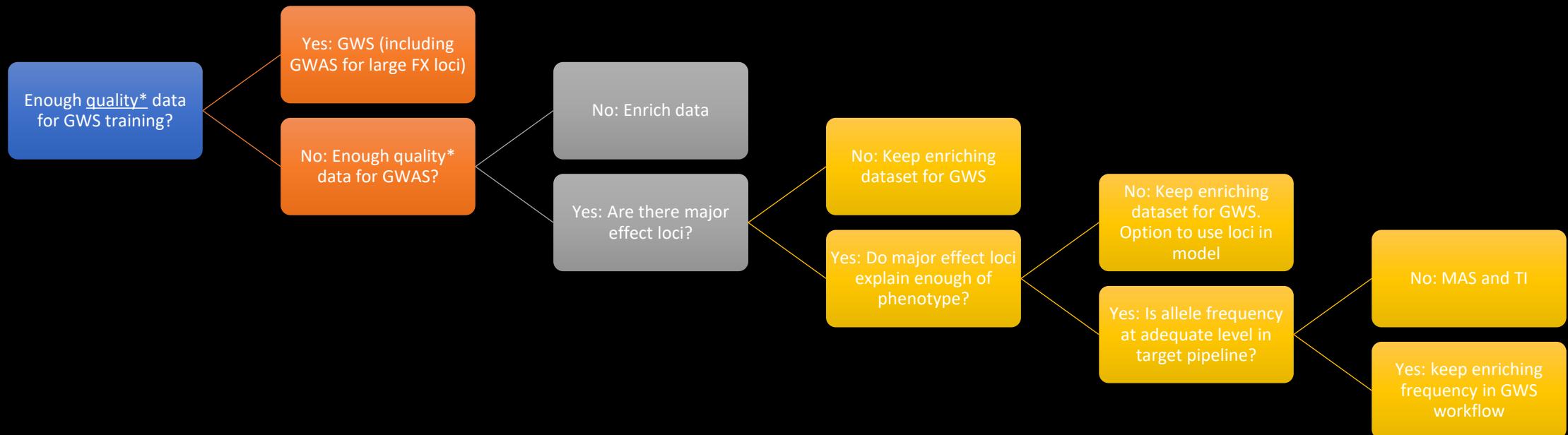
# How Genomics Technology Impact Breeding Pipeline



# Pipeline or project approach with possible genotypic selection workflow outcomes



# *Proposed Pipeline trait decision tree*



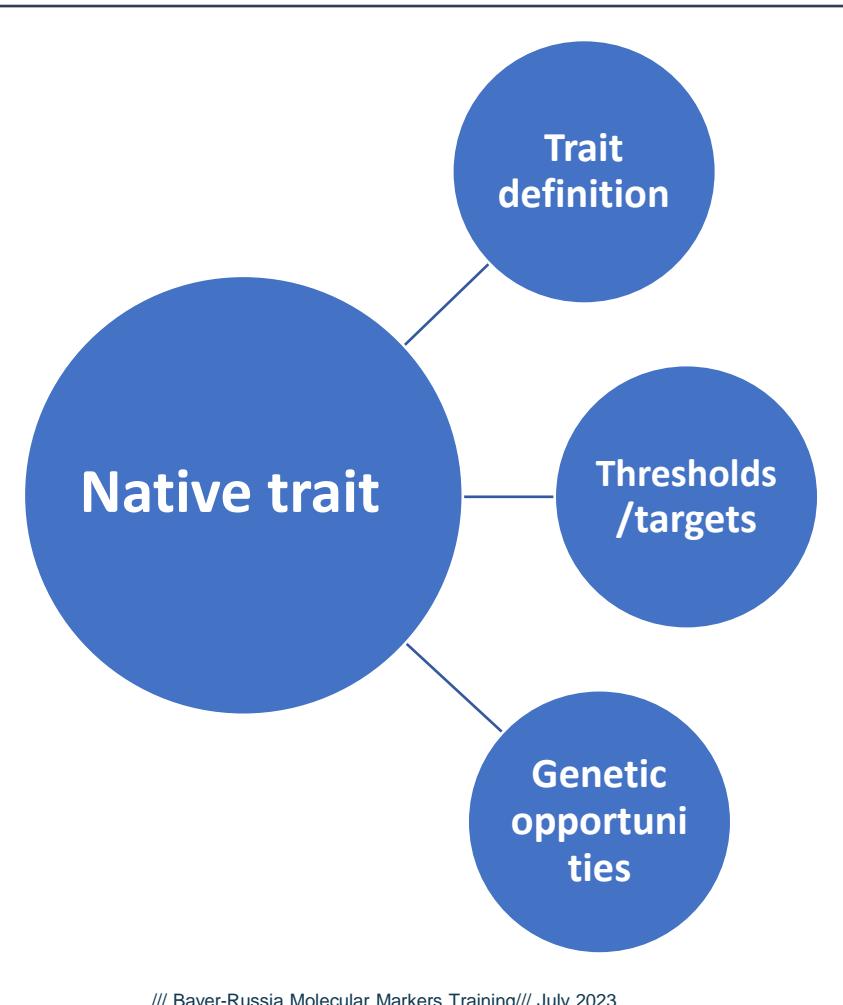
\* Quality for GWS is defined by data pyramid. For GWAS it is less stringent?

# Trait characterization and phenotypic variation characterization

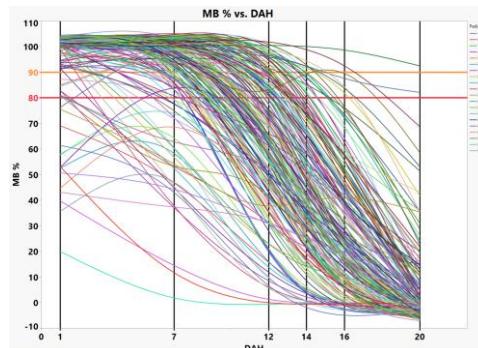
Field → Packhouse → Transport → Wholesale → Retailer → Supermarket → Consumer



From field observation on plot level



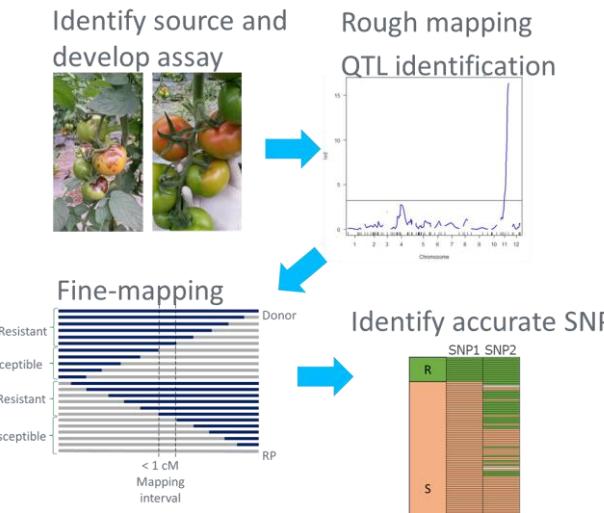
Investigate phenotypic variation



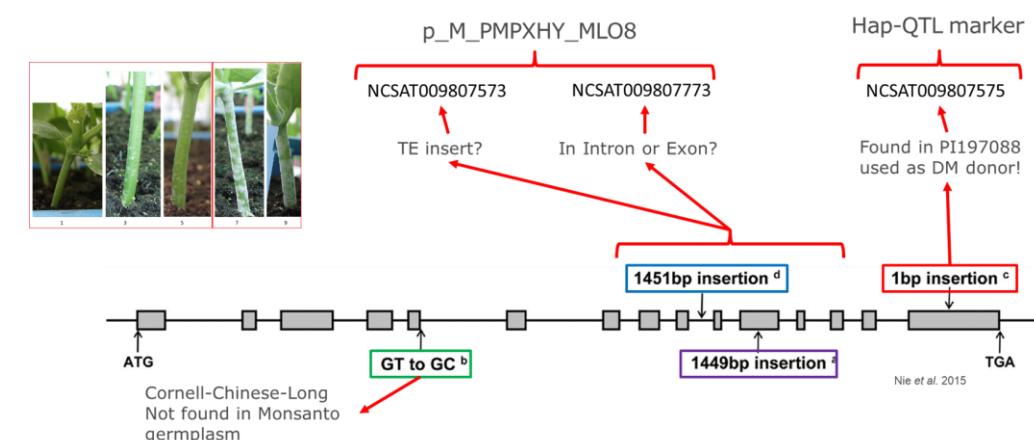
# MAS-Enablement

## Different Approaches for discovering and enabling selection of large-effect trait loci

### Biparental Mapping



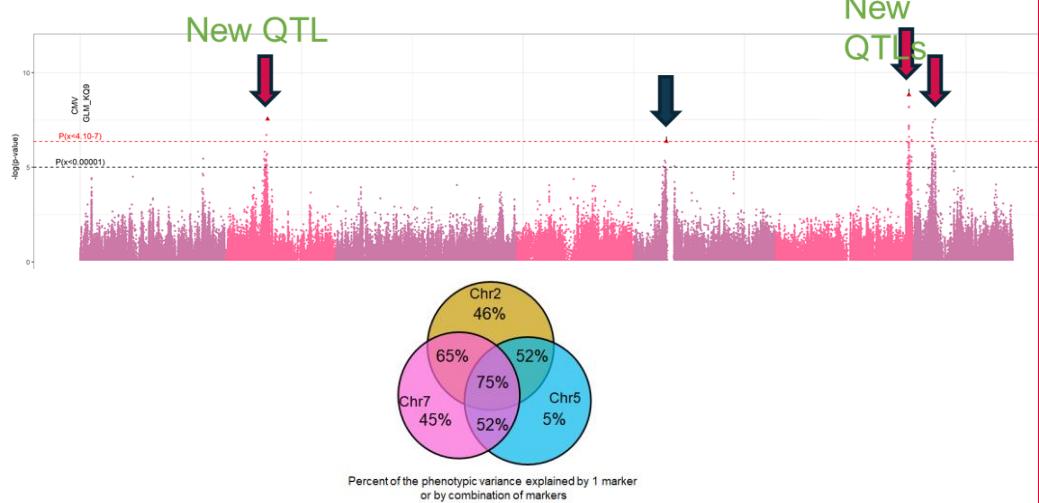
### Published alleles



# MAS-Enablement

Different approaches for discovering and enabling selection of large-effect trait loci

## GWAS

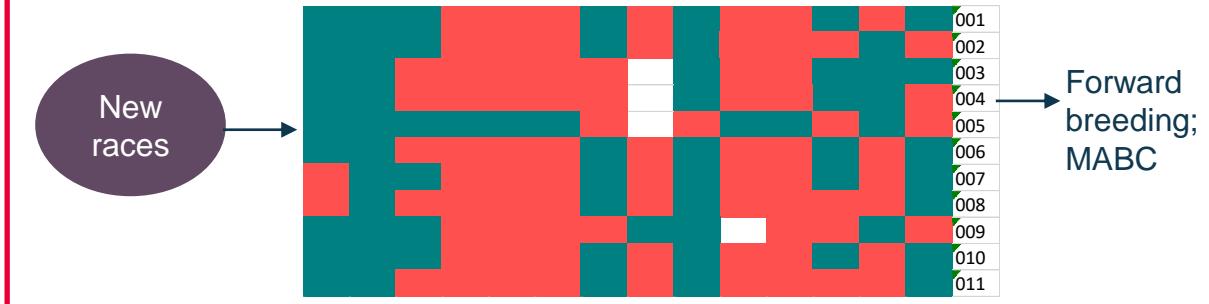


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## Allele mining

Characterize wild haplotypes and fix novel ones for faster phenotyping and deployment

### Haplotype library



## Trait information across the crops



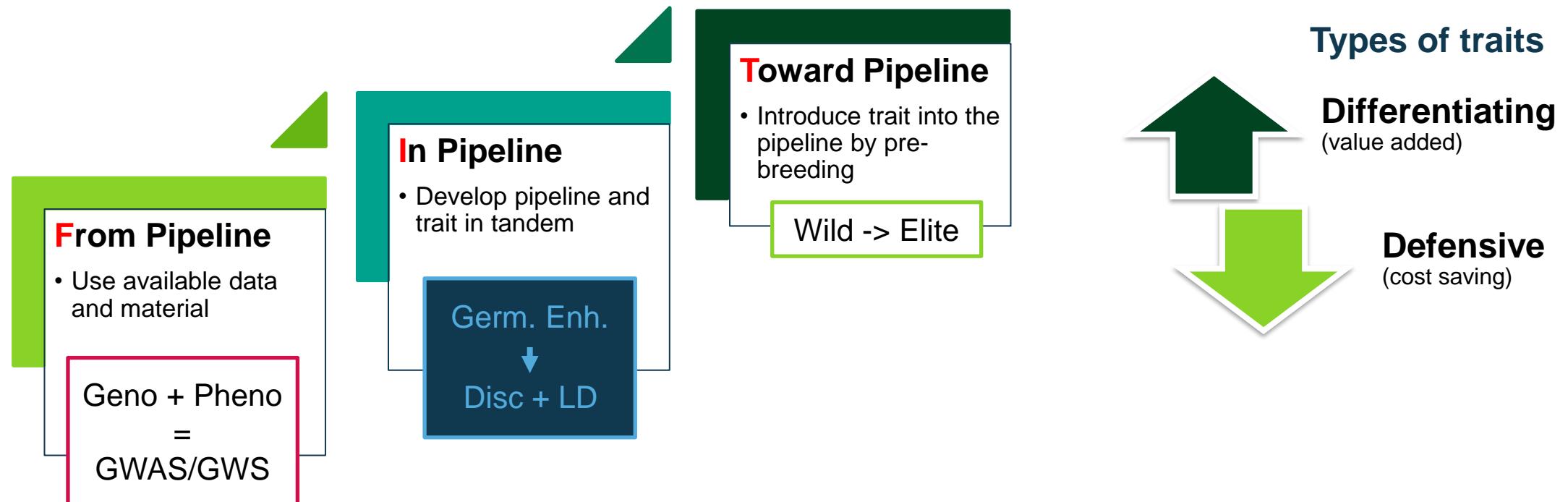
Internal database and software to enable efficient data curation, interpretation and decision making

# Pipeline Discovery Initiative



## Work FASTER and more EFFICIENTLY

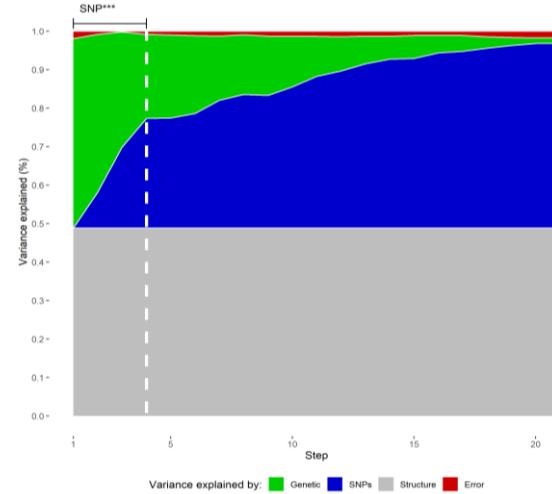
Integrated and optimized global discovery pipeline where workflows maximize use of pipelines for trait discovery work



Collaborative Breeding Pipeline team

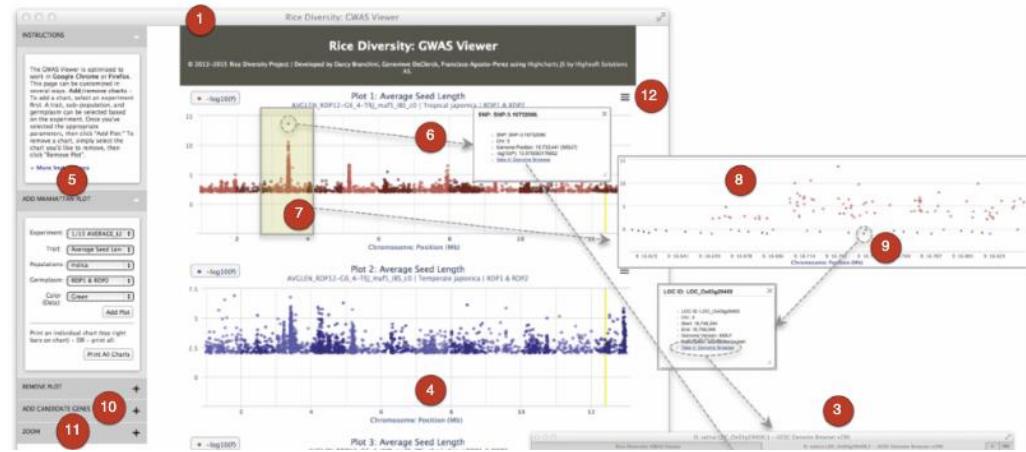
Breeding Technology

# Improving Native Trait discovery with data from the pipeline



Data access

Analysis



Empowerment

GWAS

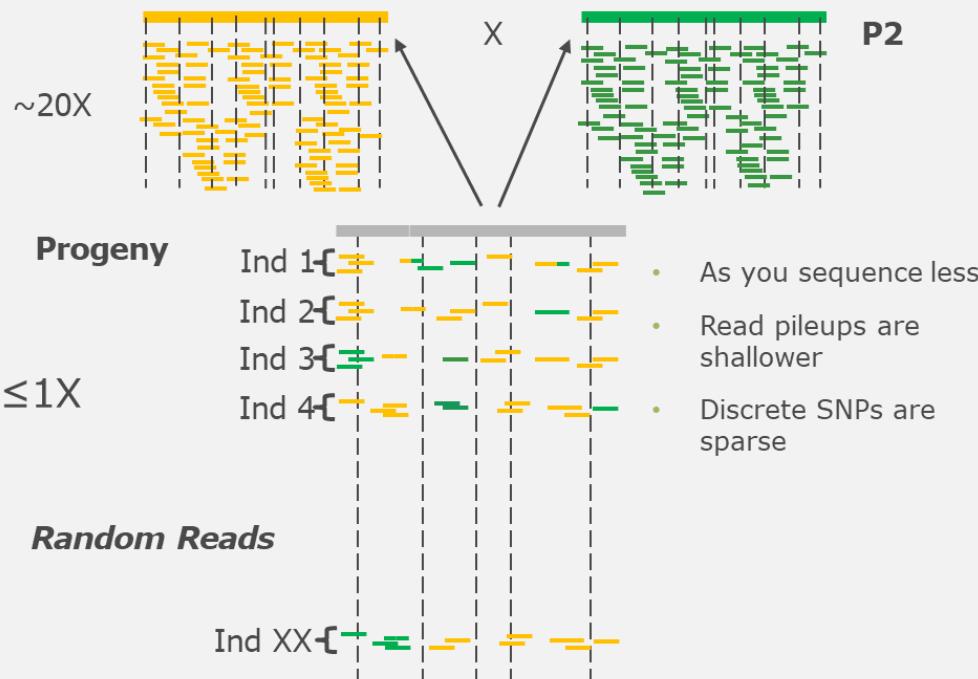
DOI: 10.1038/ncomms10532

# Tools to accelerate deployment of traits in and towards the pipeline



## Sequencing technologies

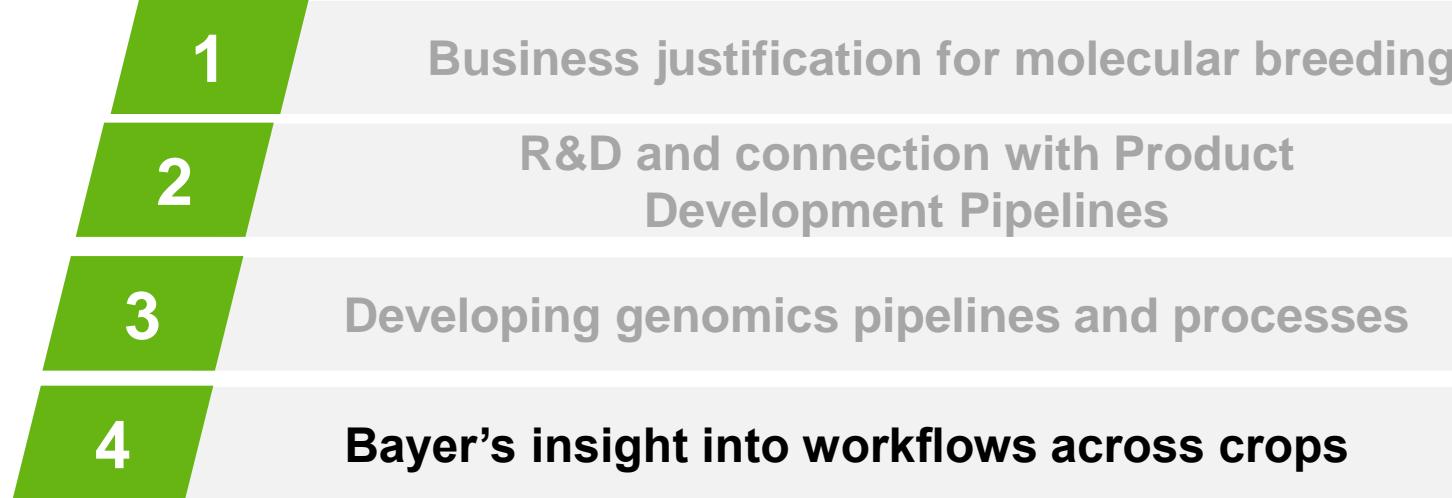
### Low Coverage-seq for hi-res one-step mapping



### HiFi seq for differentiation of structural variation alleles



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# Grower Needs and Economic Value-Based Indices Will Drive How We Design Improved Products

100% of new deployments will be based on customer insights and economic selection indices

## Customer Data & Insights @ Scale



Generate **data-driven** ideas based on customer needs and insights

## Reimagining Our Approach



### Customer Insights

Surveys combined with external and internal data to build indices based on trait value for each customer



### Objective Selection Indices

Can adjust, track and understand impact of changes

## Breeding 3.0

- One** path through the pipeline
- One** set of operations per stage
- One** testing design per stage
- One** cohort per decision

## Precision Breeding

- Many** paths through the pipeline
- Multiple** operational pathways
- Multiple** testing plans
- Multiple** cohorts per decision

## Customer Designed Solutions



Next generation of customer design product solutions enable **new business models**, improve **customer experience** and are **tunable to global environmental changes**

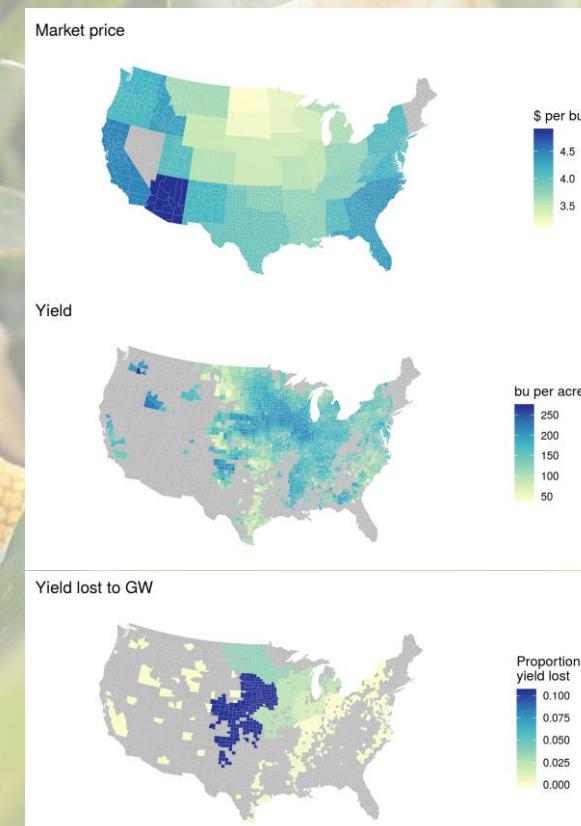
# Leveraging Multiple Sources of Data to Improve the Precision of our Selection Approaches

*Grower needs are objectively quantified and selection strategies are tailored to each grower typography*

## Multiple Diverse Sources of Data



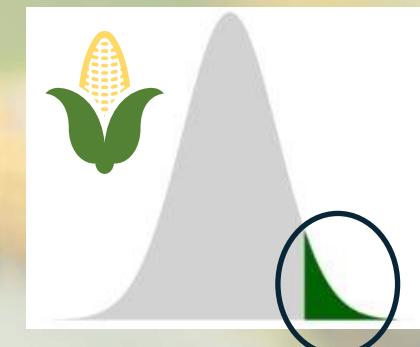
## Estimate How Predicted Outcomes Impact Value



## Selection Approach to Maximize Gain Across Multiple Traits

$$\begin{bmatrix} \mu \\ f \\ m \\ h \end{bmatrix} = \begin{bmatrix} X'R^{-1}X & X'R^{-1}W \\ Z_f'R^{-1}X & Z_f'R^{-1}Z_f + G_f^{-1} \otimes \Delta_f \\ Z_m'R^{-1}X & Z_m'R^{-1}Z_m + G_m^{-1} \otimes \Delta_m \\ W'R^{-1}X & W'R^{-1}W + G_h^{-1} \otimes \Delta_h \end{bmatrix}^{-1} \begin{bmatrix} X'R^{-1}y \\ Z_f'R^{-1}y \\ Z_m'R^{-1}y \\ W'R^{-1}y \end{bmatrix}$$

$$KPI = \sum_i^{nBEI} \sum_j^{nLines} a_i b_{i,j} x_j$$





# *Consumer-Driven Pipeline*

Disease resistance. Yield potential. Ease of harvest. These are all important factors that growers take into account when selecting vegetable seed varieties. While these traits are essential in ensuring healthy crops, growers and value chain partners are increasingly focused on what's needed beyond the farm. From flavor and color to convenience and nutrition, consumer preferences play a critical role in helping create market demand and advance health and nutrition worldwide.

But understanding – or better yet, predicting – consumer liking is no easy task. As part of our Vegetable Seeds approach to innovation, we are going above and beyond to increase our understanding of the drivers of consumer preference to ensure our varieties deliver what people around the world want and need to eat. In doing so, we're helping growers not only build a healthier business, but a healthier, more well-nourished world.





# Consumer-Driven Pipeline

## Solutions:

Data innovation enables our team to dissect the flavor drivers in a tomato or melon, for example, and predict whether a consumer in different parts of the world might prefer that variety. In doing so, we take what is often subjective – an individual's preference – and turn it into quantifiable data that helps ensure our varieties have the right recipe for flavor long before they reach the consumer's plate.

// *predictive consumer liking models*

## Results:

**4,500+**

*consumers contributing to sensory insights across numerous countries (2019)*

**>500,000**

*data points measured in our Vegetable Quality Labs informing future variety selection*

**Ground-breaking flavor year-round**

*in varieties like Delisher tomato and Crave™ Cantaloupe Series*

## //// Key Takeaway

By leveraging our expertise and deep understanding of consumer preferences at every stage of our pipeline development, we are helping growers maximize their investment in our products by creating more pull from the market, while maintaining the agronomic traits that are essential to ensuring a healthy harvest.

***"We are creating pull from the market to help grow farmers' businesses and increase vegetable consumption."***





# Q&A Discussion





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