New Breeding and Genomic Selection Techniques

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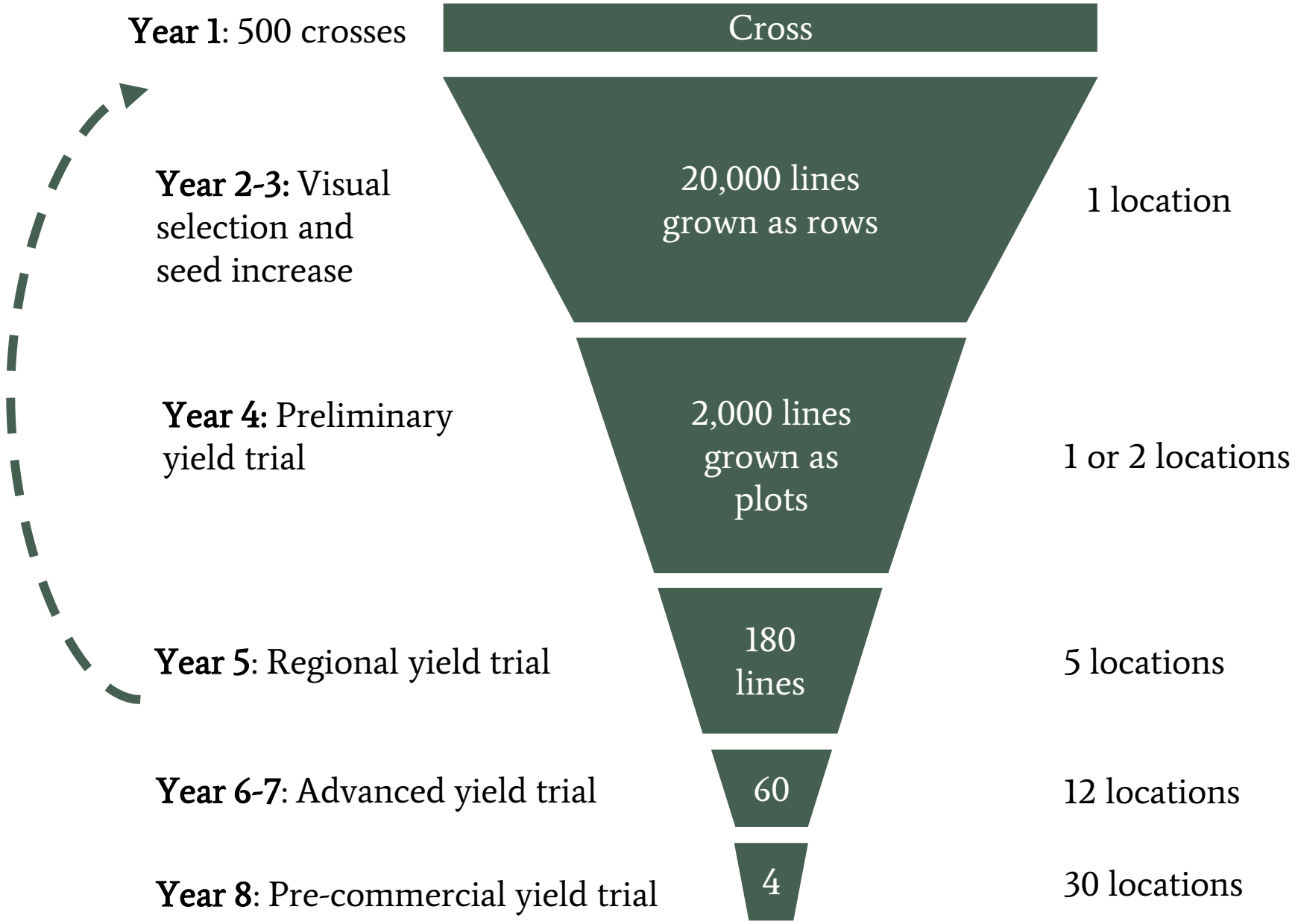
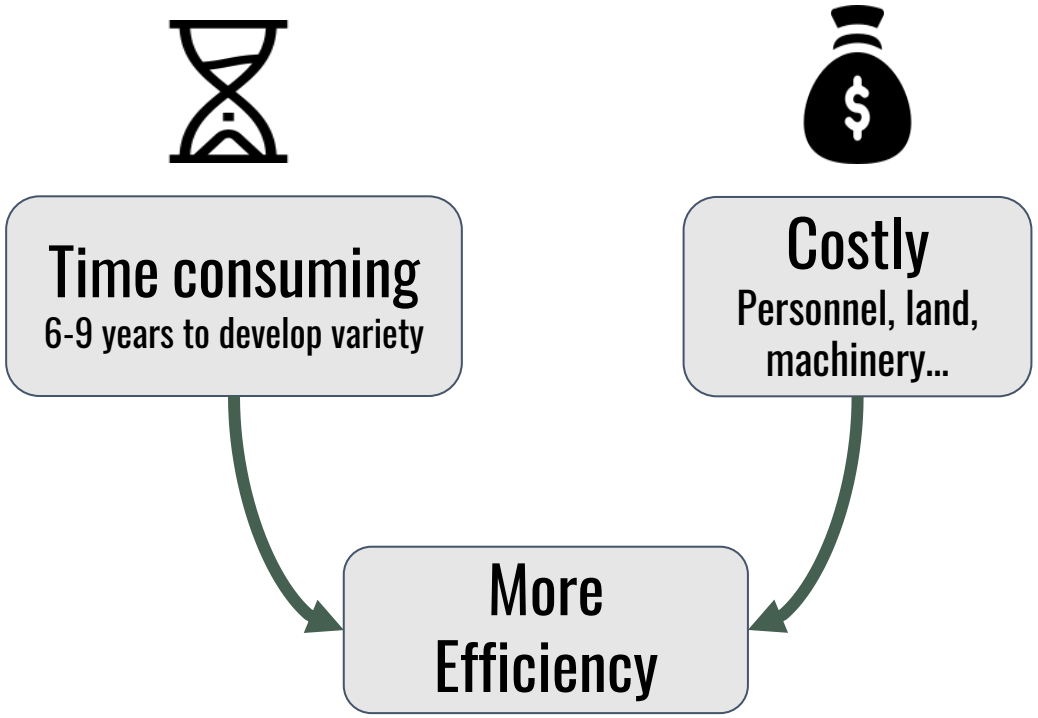
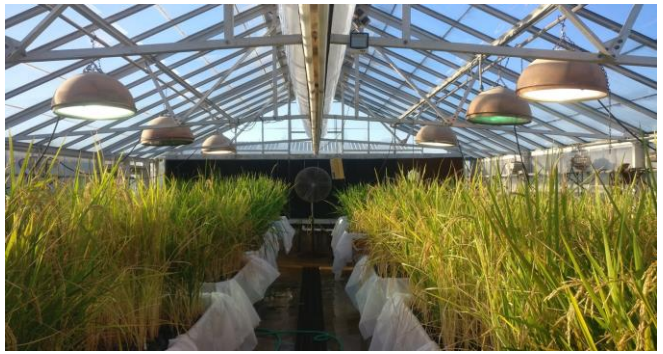
Rice breeding pipeline

Every year the LSU breeding programs develops 20,000 new unique experimental while others are tested and selected.



Plant breeding always needs improvement





Plant breeding has always been revolutionized by new discoveries and technologies

10000 BC

Phenotypic Selection

~1900

Genetics
Selection strategies
Mutation
Hybrids

~1950

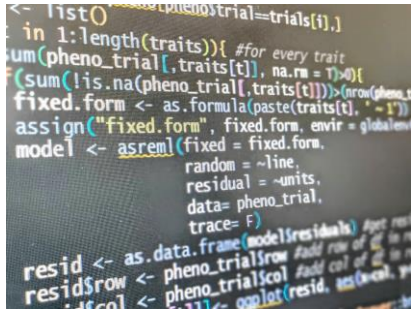
Controlled Trials
Quantitative genetics
Statistics
Experimental design

2000s

Molecular Markers
Simple traits
Marker Assisted Selection

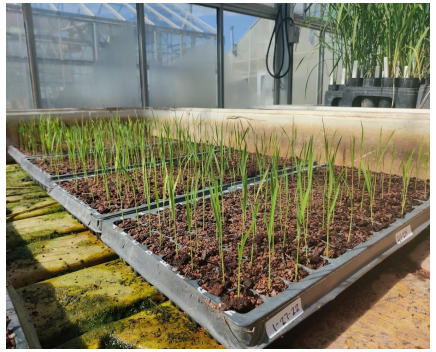
2010s

Genomic Selection
Complex traits
Databases
Advanced stat. models



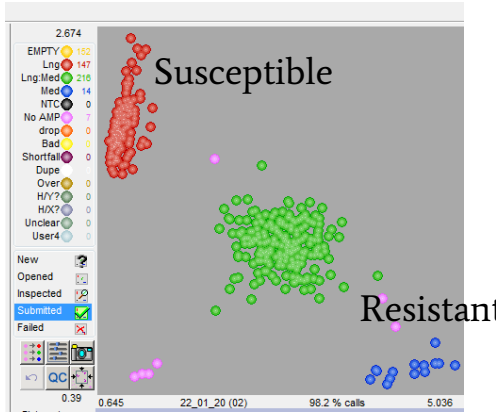
Marker Assisted Selection

Sample leaf tissue



Screen sample with desired markers

Select lines

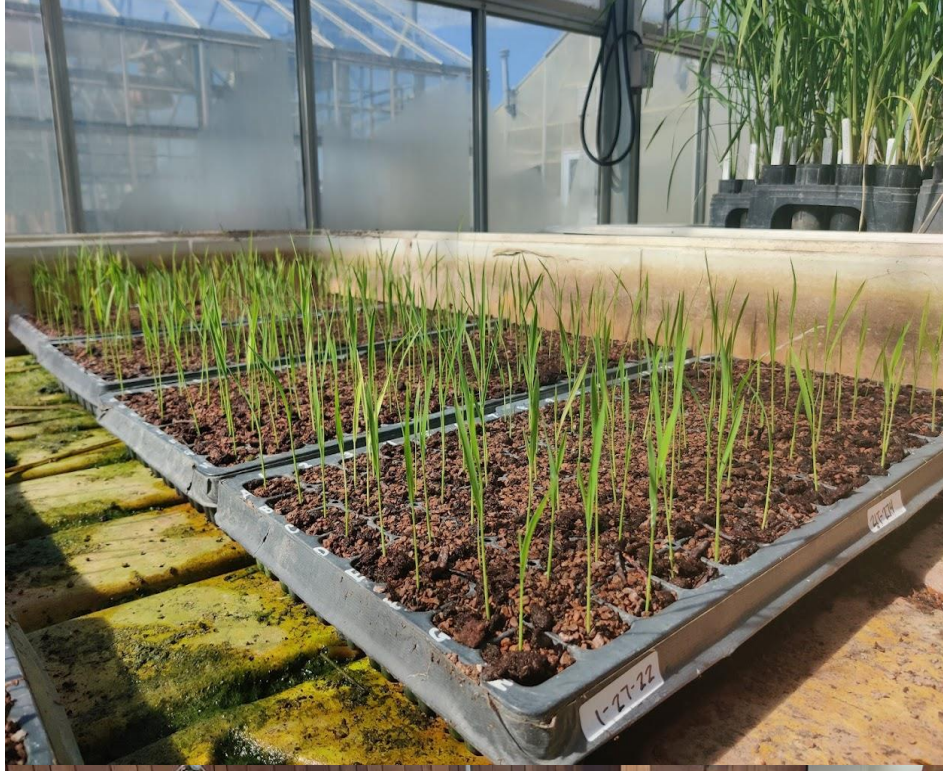


Increase the seed in green house

Test in the field for other traits

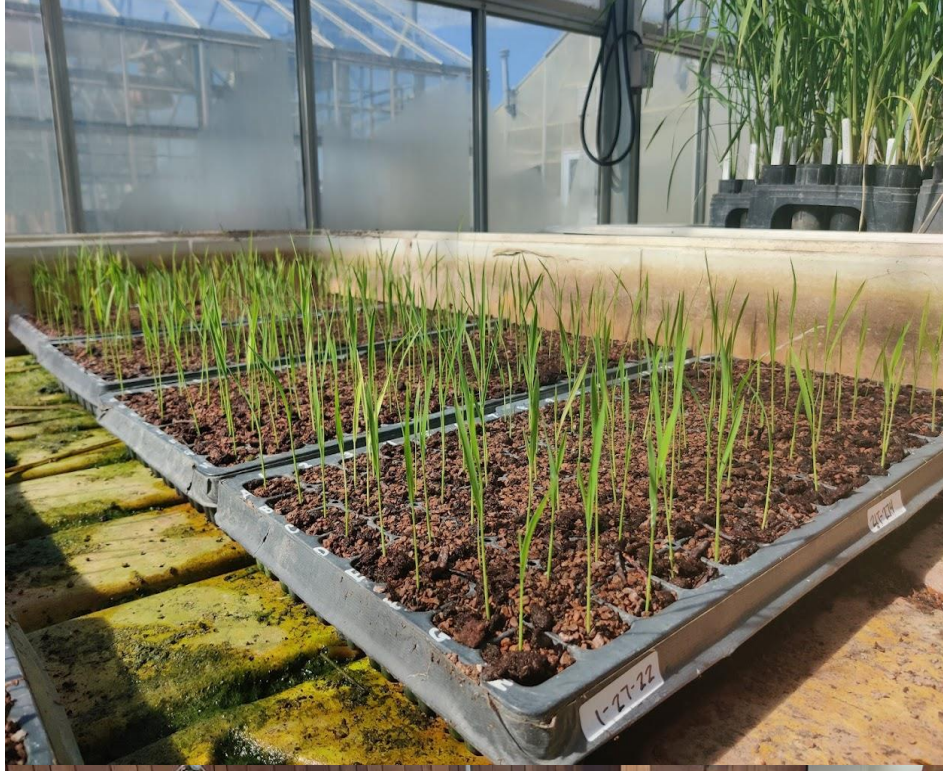
Marker Assisted Selection

- Genotyping is cheap: screen thousands of lines in reduced time.
- Select for traits hard to measure (disease resistance, amylose content, gelatinization temperature …)
- Can be conducted in green house all year long.
- Helps maintaining the purity of lines.
- Works very good with traits affected by few genes:
  - Herbicide resistance
  - Plant height
  - Blast resistance
  - …



Marker Assisted Selection

- Doesn't work with traits that are determined by **many genes** and by the **environment**:
  - Yield
  - Milling
  - Chalk
  - Sheath blight
  - Days to heading
  - …
- Requires previous knowledge of which gene affects the trait



Genomic selection

- Use of hundreds/thousands of DNA markers spread across the genome to predict the traits affected by many genes.
- Works with simple and complex traits.
- Doesn’t need previous knowledge of genes affecting the trait.
- Many advantages
- Routinely used in major crops (maize, soybean …).

Genomic selection overview

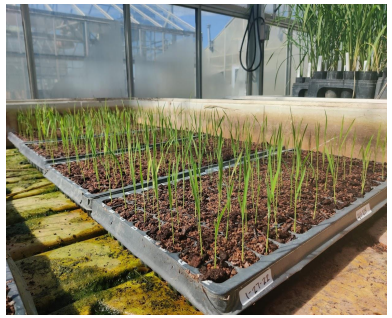
Training population

+

DNA markers of training population

Statistical model

DNA markers of new lines



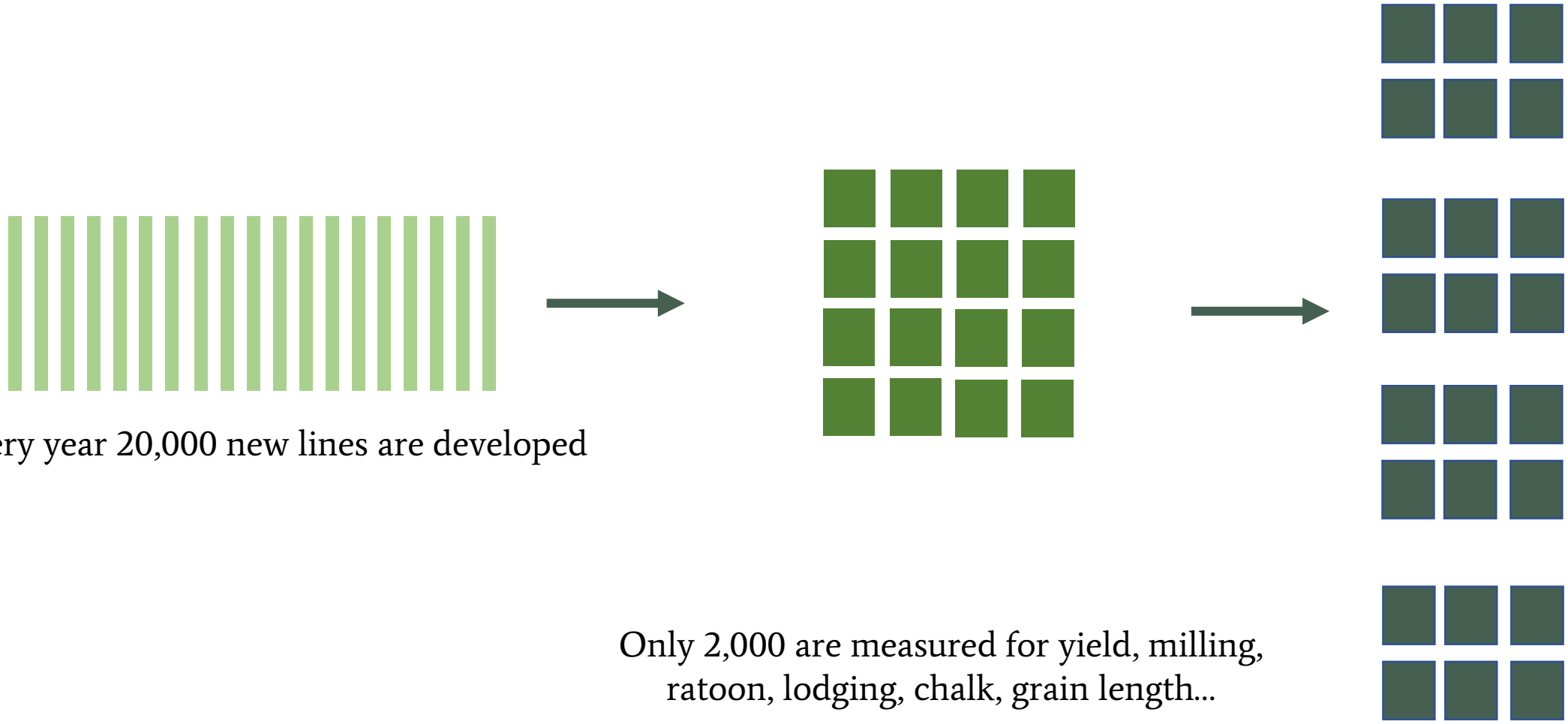
Predictions of new lines

Select and test in field

Genomic selection

- Reduce time to develop a variety
- Reduce the cost of the breeding program
- Increase size of the breeding program
- Increase the accuracy of the phenotype
- Works with all traits: simple (e.g., plant height) and complex (e.g., yield)

Increase lines tested in the breeding program

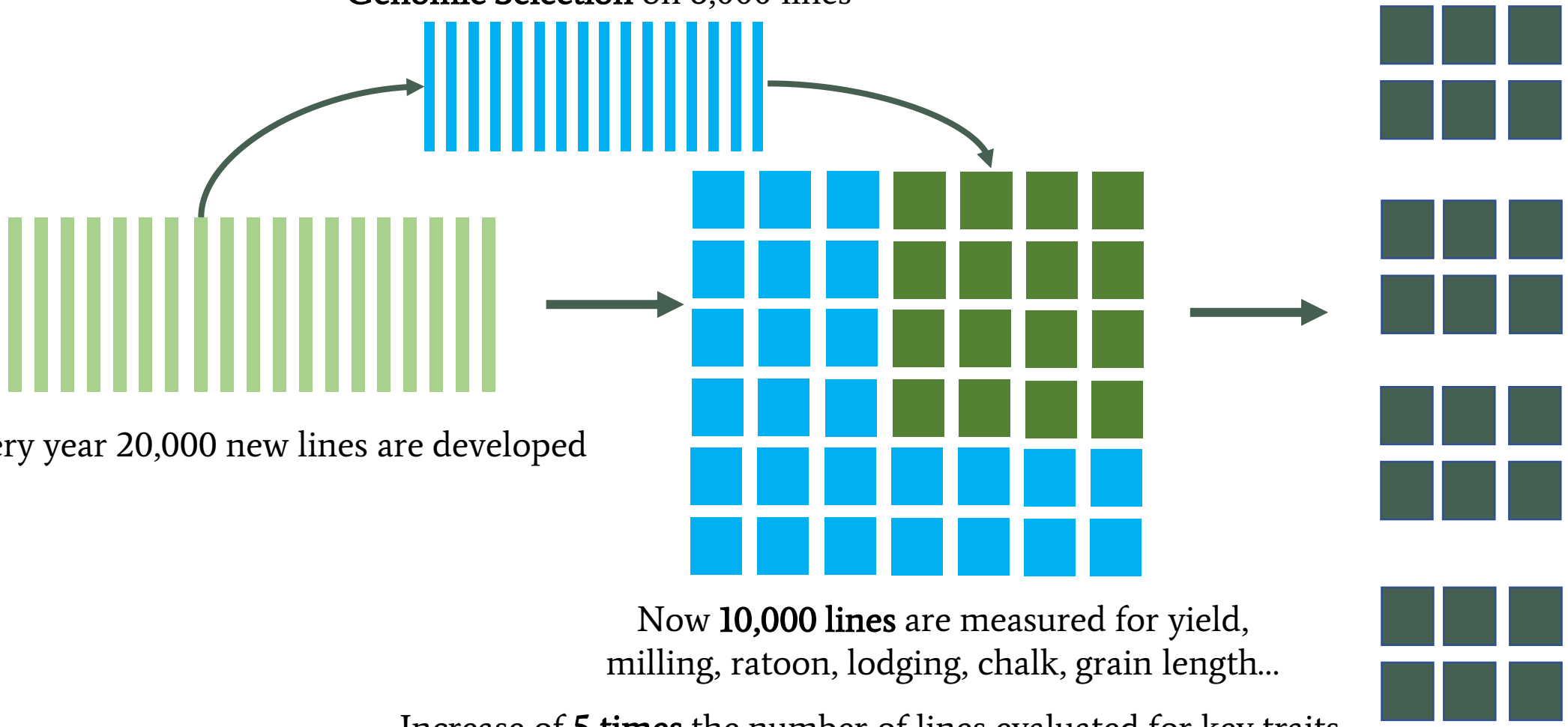


Every year 20,000 new lines are developed

Only 2,000 are measured for yield, milling, ratoon, lodging, chalk, grain length...

Increase lines tested in the breeding program

Genomic Selection on 8,000 lines

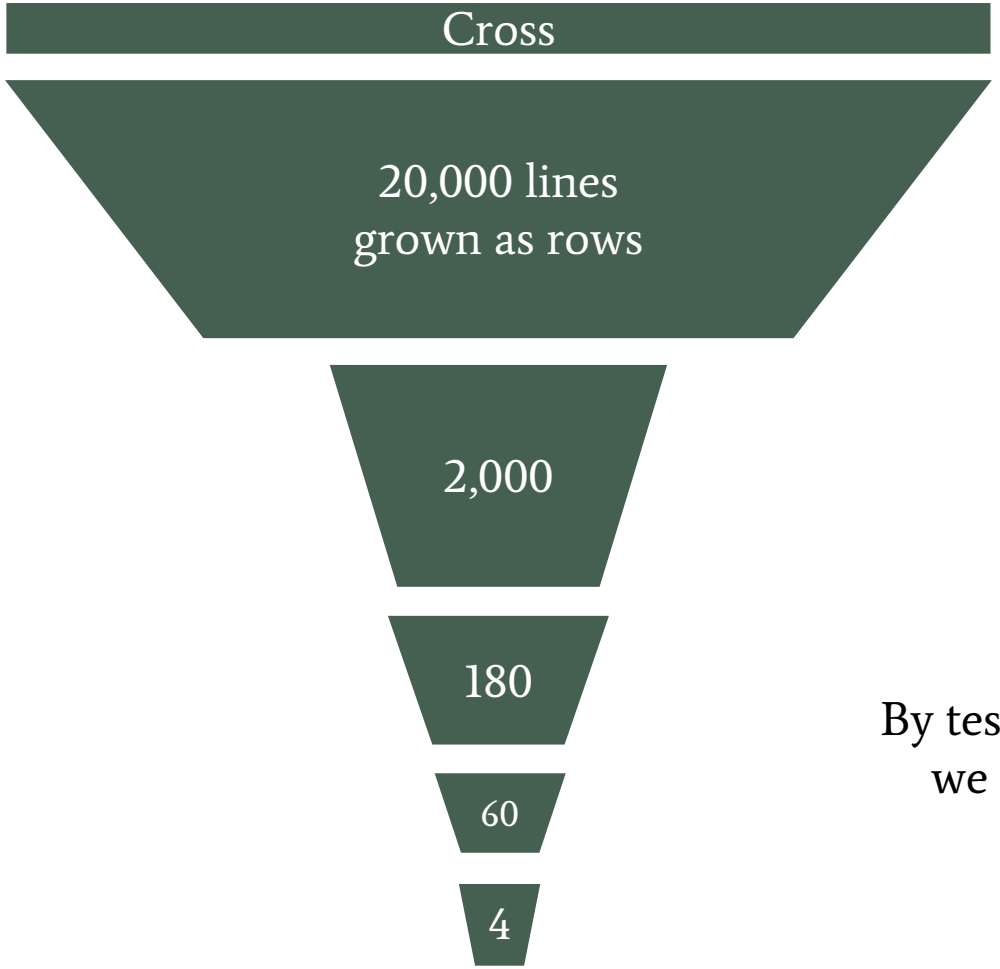


Every year 20,000 new lines are developed

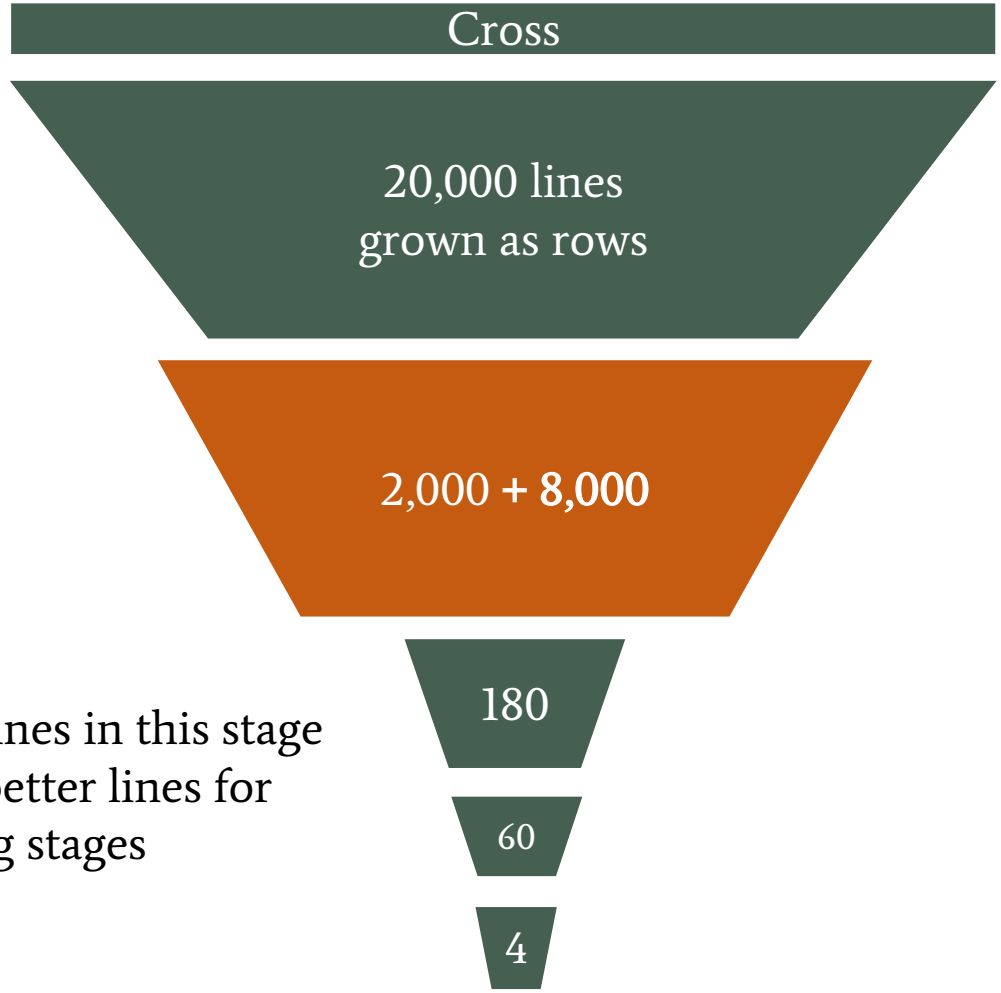
Now **10,000 lines** are measured for yield, milling, ratoon, lodging, chalk, grain length...

Increase of **5 times** the number of lines evaluated for key traits

Breeding pipeline



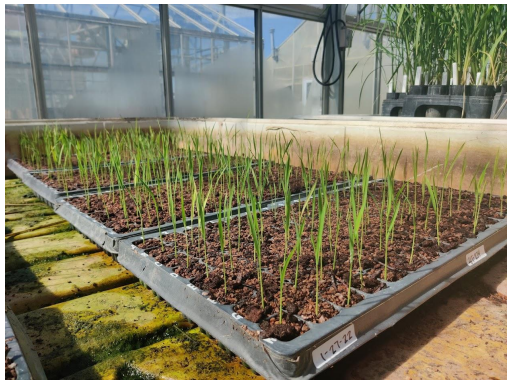
Breeding pipeline with Genomic selection



By testing more lines in this stage we will select better lines for following stages

Predict every trait

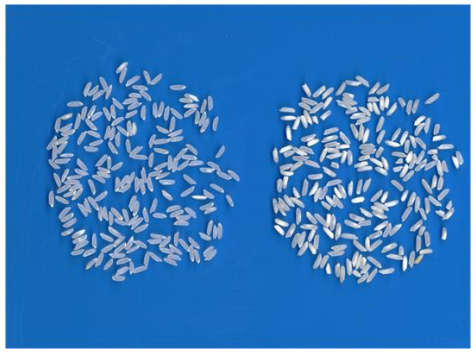
With a small tissue sample with a reduced cost and time you can predict...



Grain yield

Maturity

Milling yield/quality



Disease resistance

Limitations

- Requires large investments and changes to the breeding program:
  - Genotyping method and cost
  - Need of data management system
  - Logistics
  - Allocation of resources
  - New breeding strategies
- Large variety of skillset required:
  - Computer science
  - Statistics
  - Molecular and quantitative genetics

Genomic selection at LSU Rice breeding program station

- LSU rice breeding program started to implement genomic selection in 2017.
- Close collaboration with Cornell University computational, plant breeding, and statistics experts.
- Gradual process of implementation.
- Developed a marker set for routing genotyping.
- Established a highly organized and structured data management system.

Genomic selection example

Phenotype 2020

Select best and worst 20%

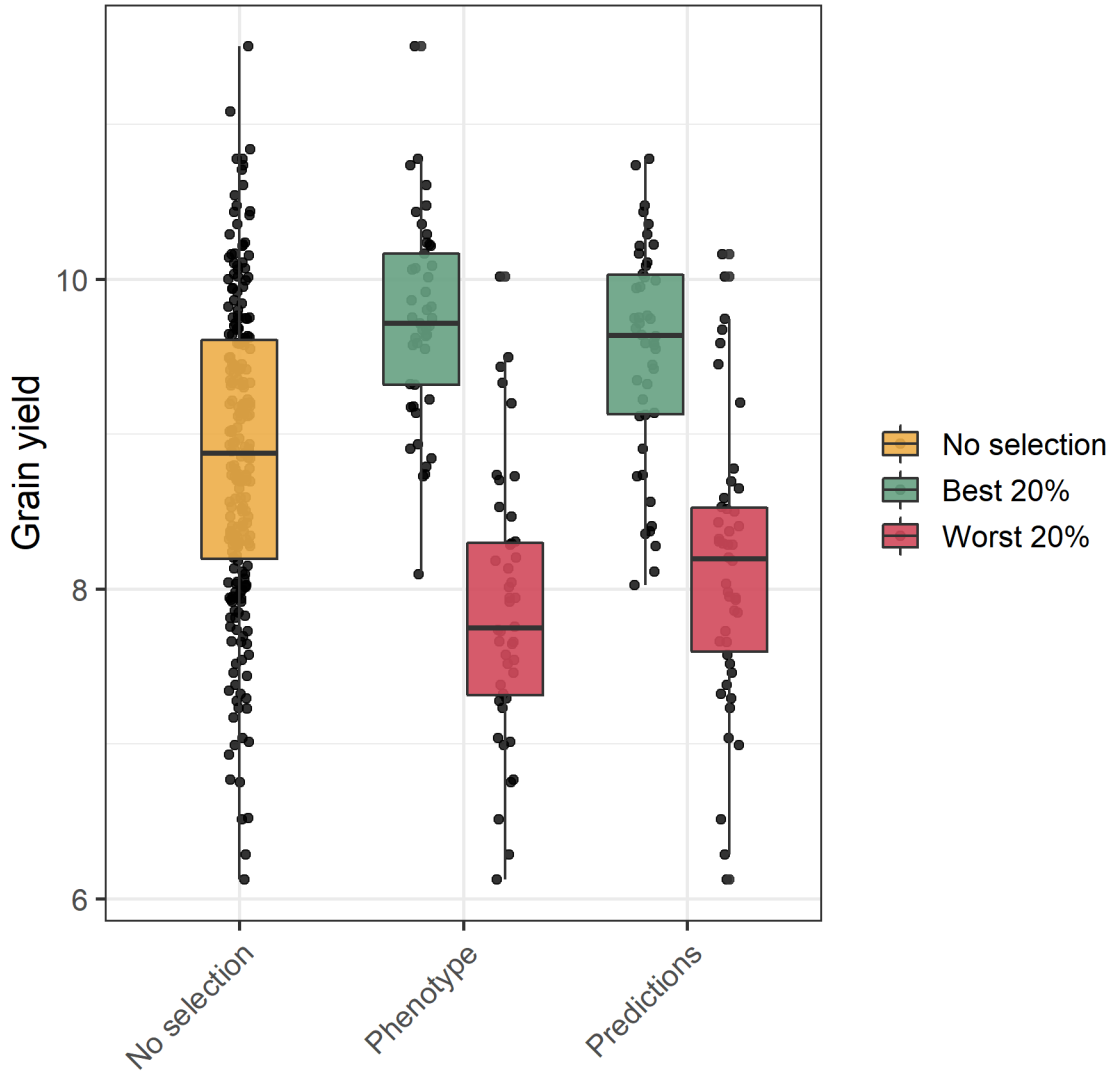
Predictions from phenotype 2018-20

Select best and worst 20%

Phenotype 2021
from 400 lines from four different elite crosses

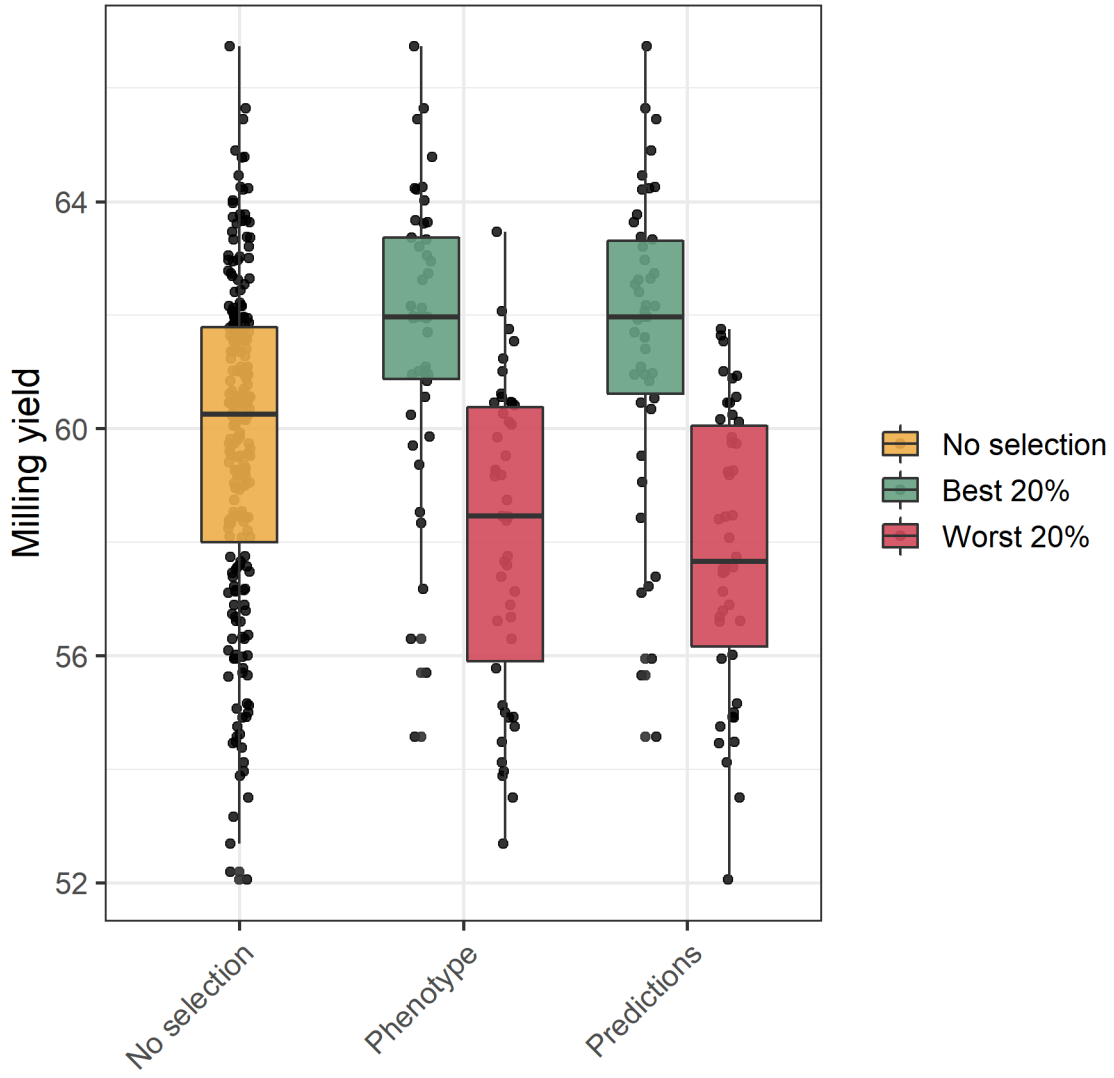
Response to selection – Grain yield

- Distribution of best lines and worst lines based on:
  - Phenotype previous year
  - Predictions from 2018-20 breeding data phenotype
- Phenotype is not 100% accurate (that's why we test many years and locations)
- Predictions are very similar to phenotype.



Response to selection – Milling yield

- Genomic selection has same accuracy as the phenotype



Genomic selection in LSU rice breeding program

- Genotyped **30,000 lines**.
- In 2020 we predicted **3,000** lines, and **8,000** lines in 2021 .
- These lines will be visually selected for maturity, plant height, and general appearance in 2022
- Then will be predicted for grain yield, milling yield, and other traits.
- The selected lines will then be tested in plots in 2023.

Final remarks

- DNA markers are the present and future of plant breeding.
- Marker Assisted Selection has been successfully implemented and has improved Louisiana rice variety development.
- Genomic selection has the potential to increase by many times the breeding program size and reduce the cost of the operations.
- Genomic selection is being implemented in the LSU rice research station and will be optimized in the following years.

LSU rice breeding:
https://lsuricebreeding.com/

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