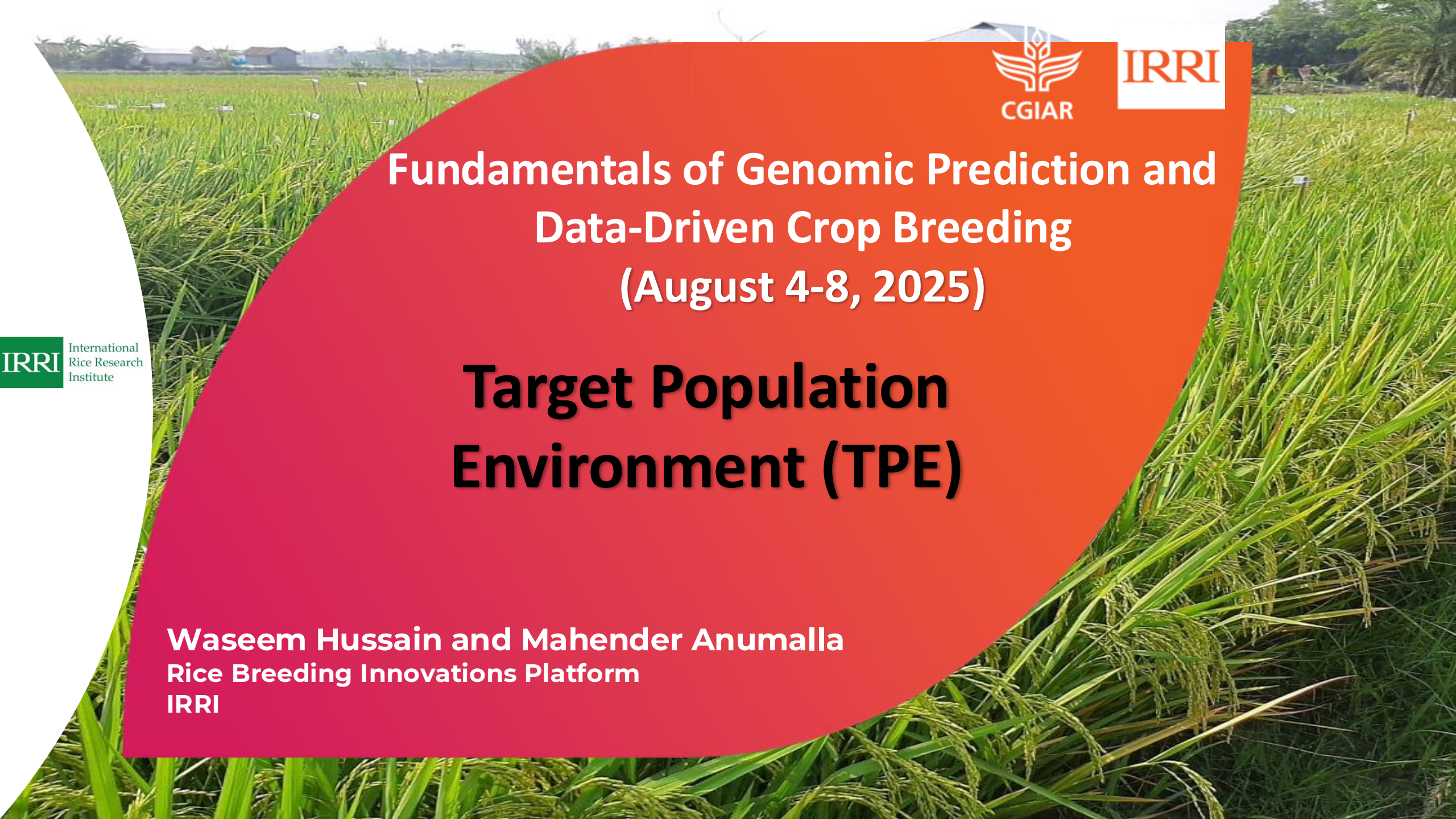

Fundamentals of Genomic Prediction and Data-Driven Crop Breeding
(August 4-8, 2025)

Target Population Environment (TPE)

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Target Population Environments (TPEs)

Target Breeding Program aims to deliver improved varieties.

Outline

01 Why TPE & How to Implement

02 Challenges in TPE

03 Where and When to Use Sparse Test Design (STS)

04 Case studies
Demo in R

05 Conclusion

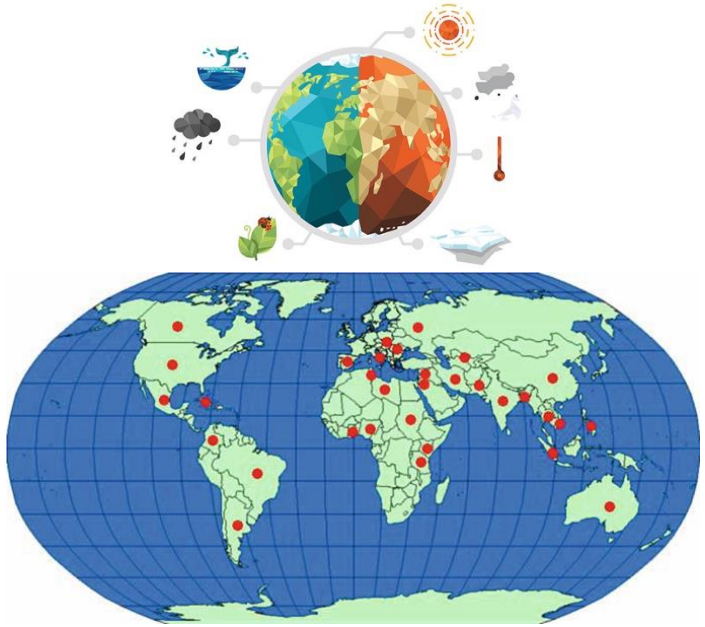
Why TPE?

❖Aligns breeding targets with real-world environmental conditions.

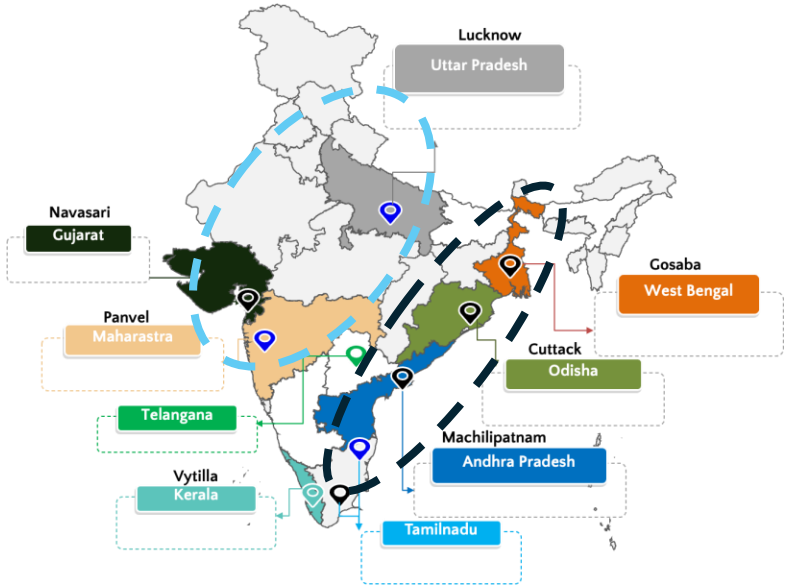
❖Enhances relevance and adoption of varieties

Target Regions → **Close TPE** → **Critical selection**

Complex environment



Aim to develop varieties that are either broadly adapted across the TPE

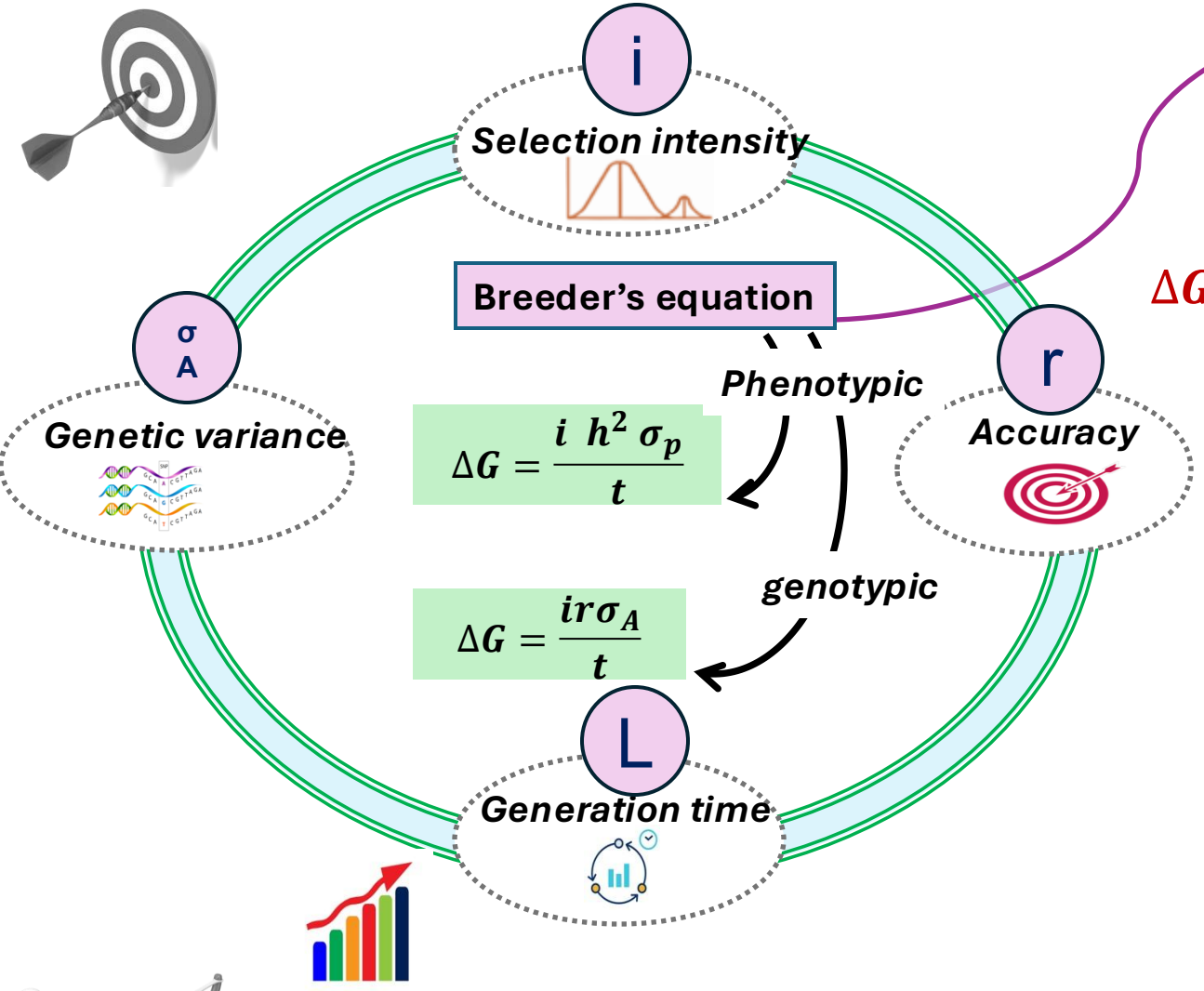


Correlations across studies

Analyse G x E Interactions

Sample representative for locations

Genetic Gain in Context of TPE: Extended Breeder's equation



It is used to predict the response to selection for a breeding program cycle

$$\Delta G_{(MET,\ TPE)} = i(MET) r_a(MET) r_a\ (MET, TPE)\ \sigma_a\ (TPE)$$

$r_{a(MET,TPE)}$ is the genetic correlation between the **additive genetic effects estimated by models** developed using the MET training data sets,

$r_{a(MET,TPE)}$: can range from **+1,** with good MET-TPE alignment, to **-1,** with poor MET-TPE alignment.

$\sigma_{a(TPE)}$ represents the relevant target additive genetic variation for the traits within the TPE

TPE's Role: Improves "*r*" by better matching selection environments to target environments.

Composition of Genetic Materials in TPE in MET conditions

$$\Delta G_{(MET,\ TPE)} = i(MET) r_a(MET) r_a\ (MET, TPE)\ \sigma_a\ (TPE)$$

Best Genomic Prediction Strategies

Firstly: $r_{a\ (MET,TPE)} \rightarrow +1$ (Accurate Sample Size and Composition)

- σ_a of equation converges to the well $\sigma_{a(TPE)}$ of equation

If huge G x E conditions, MET & TPE, $r_{a\ (MET,TPE)} < +1$ (Low Prediction Accuracy)

- Such case, lower expected ΔG in TPE, when dealing with MET of training data

Therefore, $r_{a\ (MET,TPE)}$ needs to be careful create training data set

- Best Prediction accuracy depends on best quantify training data for MET

Sparse Test Design: Not all genotypes are tested in all environments.

Crossing Block
(Elite x Elite)

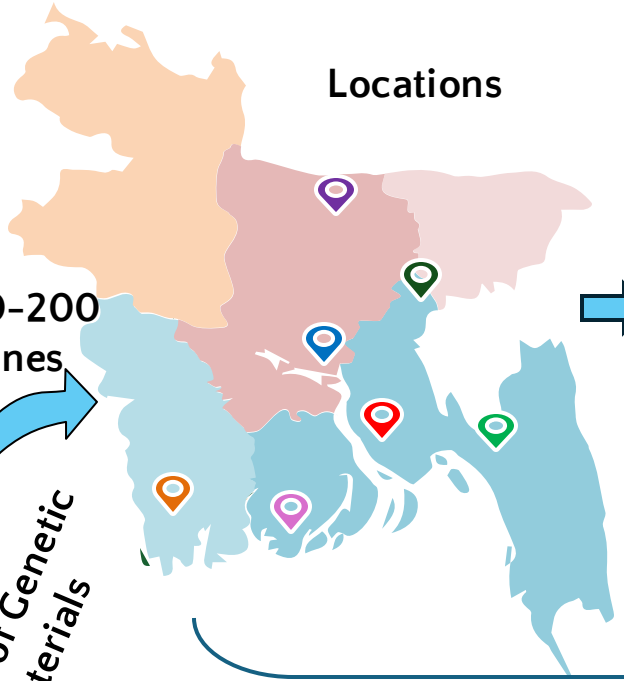
F5/OYTs

~1200

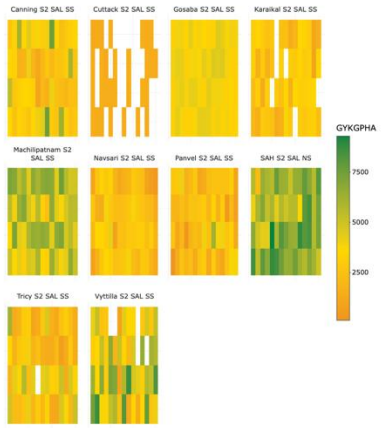
With GRM

Subset of Genetic materials

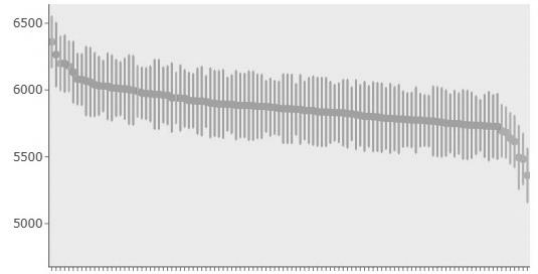
150-200 lines



Locations

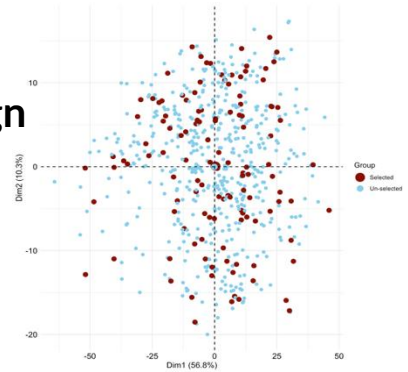


Grain yield



Ranking

Super Saturated Design
K-means Algorithm
E-NE
PVE means
CD Means



Biggest Challenges to Dissect G x E

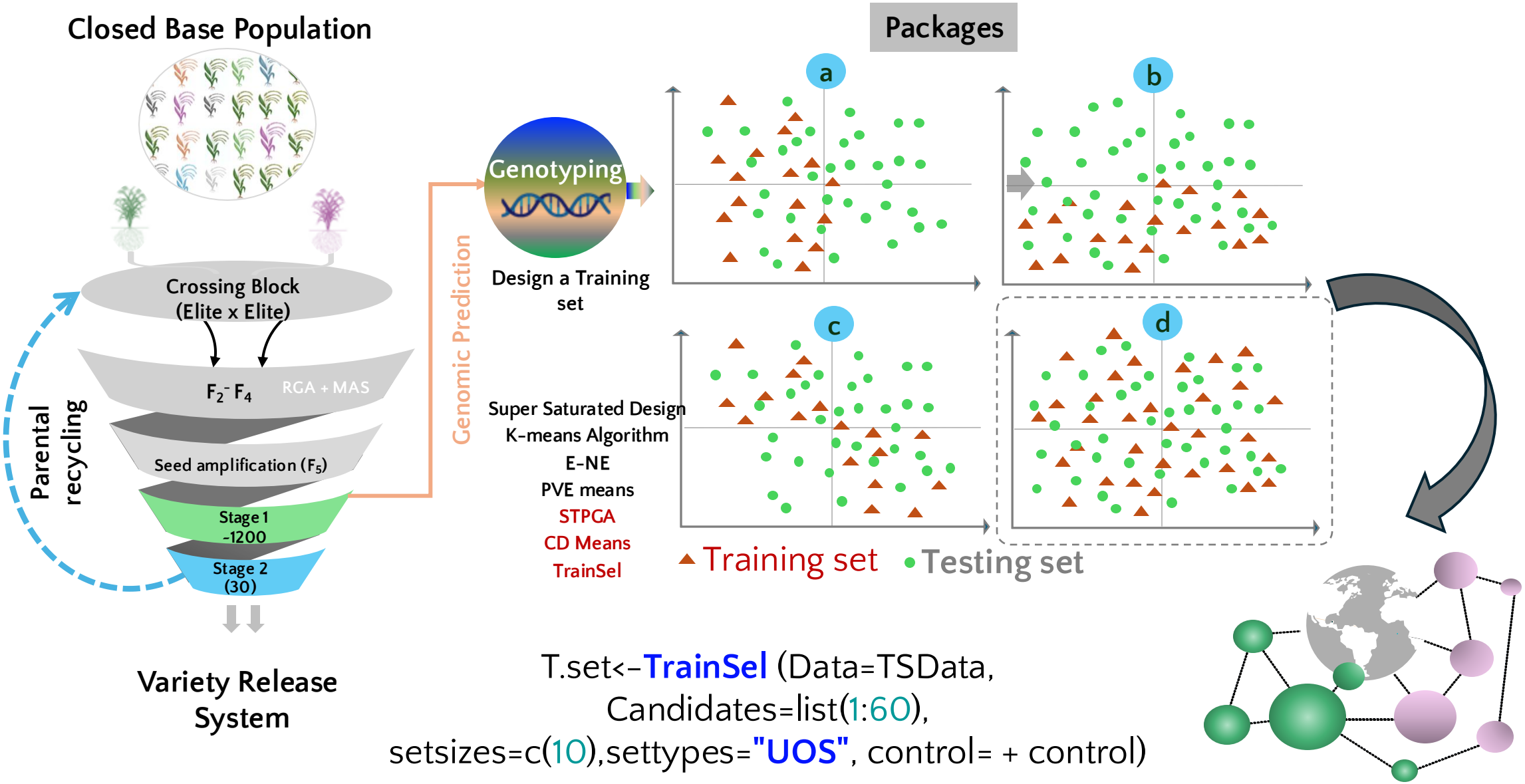
Low Heritability & High G x E Interactions

- H2 depends on stress intensity
- Strong Cross-over pattern

Spatial variability & Poor Covariance structure

- High variability in the field
- Different across locations

Optimization of Training Set

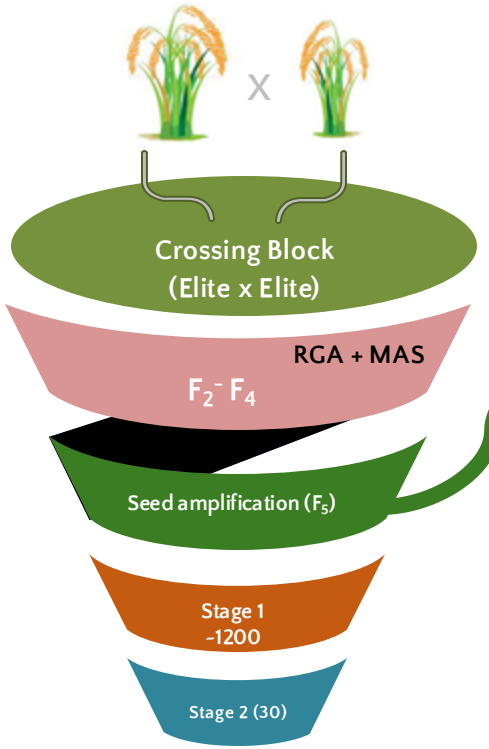


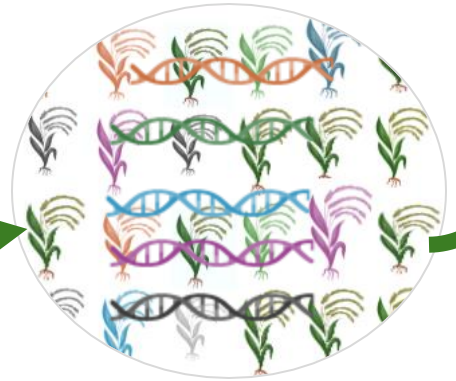

```
T.set<-TrainSel (Data=TSData,
Candidates=list(1:60),
setsizes=c(10),settypes="UOS", control= + control)
```

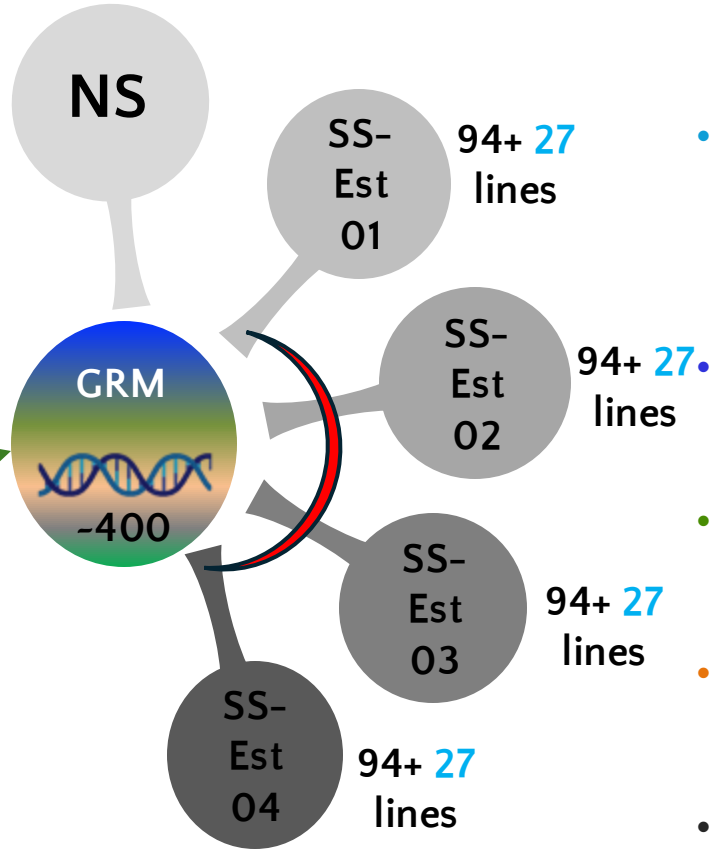
Unique Sparse Test Design (STD) for Complex Ecosystem

Connecting Locations through Replicating Alleles

Not all genotypes are tested in all environments.





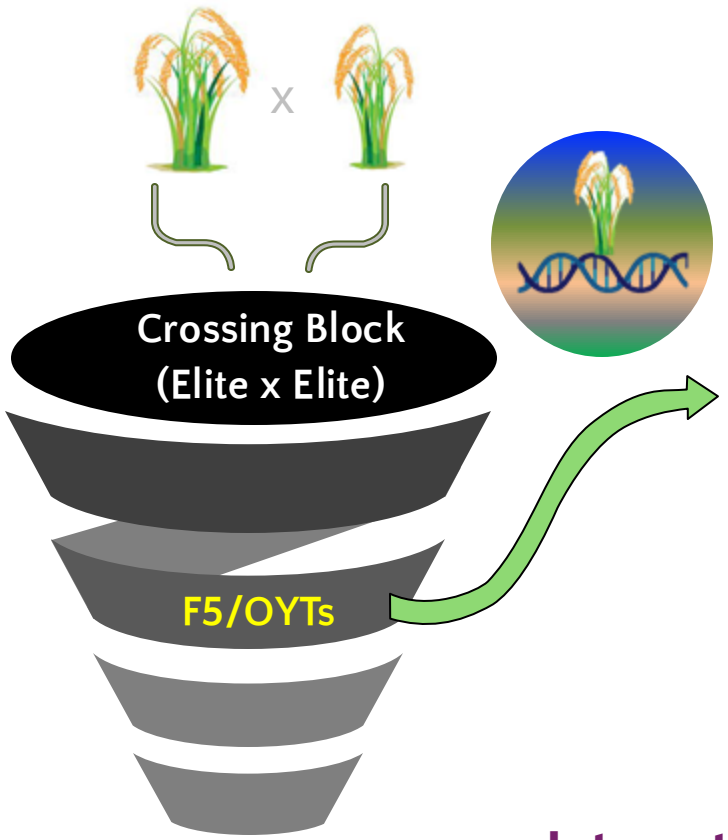


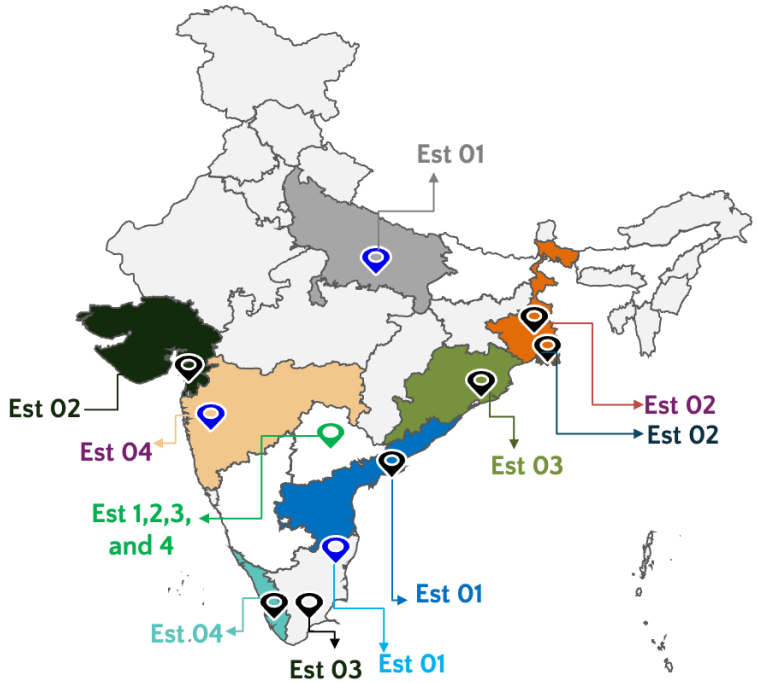
Common lines: 27;
Unique lines 94/Locations

- Screen all the entries in different locations
- Connected all the entries through GRM and better characterized environment
- Improved genomic prediction for all entries
- Easily predict the missing lines in severe stress conditions
- Dissect G x E in a much better way
- Better characterize all environments

Connecting Locations and capturing dynamic variability, and minimizing Interactions

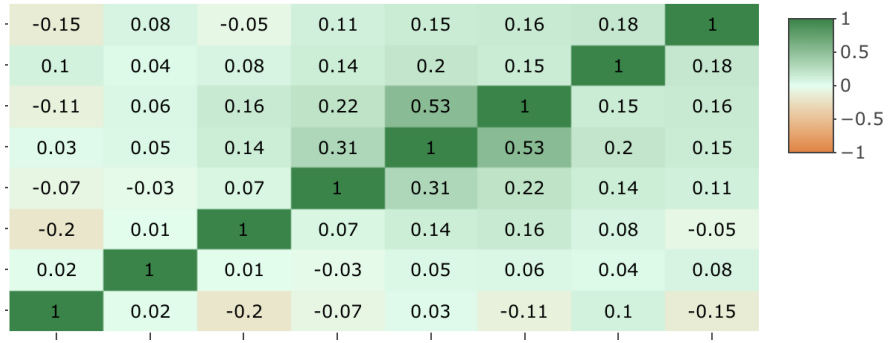
Example: Implement STD in 2024



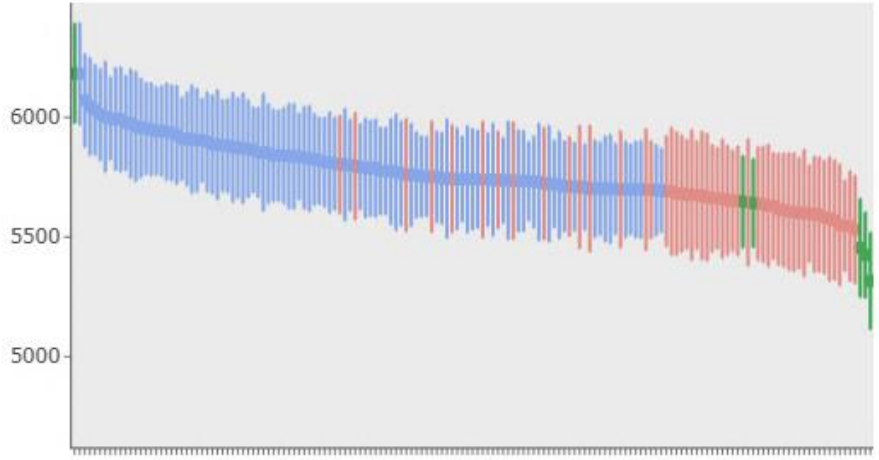


Sparse Test Design (STD)

Genetic Correlations



Breeding values: Ranking



Integrating TPE, G × E, and Sparse Testing

- Increases selection accuracy.
- Enhances resource efficiency.
- Accelerates genetic gain.

Challenges and Future Directions

- Defining TPE boundaries.
- Well design a training set with GRM
- Integrate G x E and Robust Data Analytical Pipelines

Conclusion – Key Takeaways

- TPE-focused breeding is essential for impactful varietal development.
- Dissecting G × E and using sparse testing are powerful tools to enhance genetic gain.
- Strategic integration of these concepts can transform breeding pipelines.