Genomic Selection Algorithms

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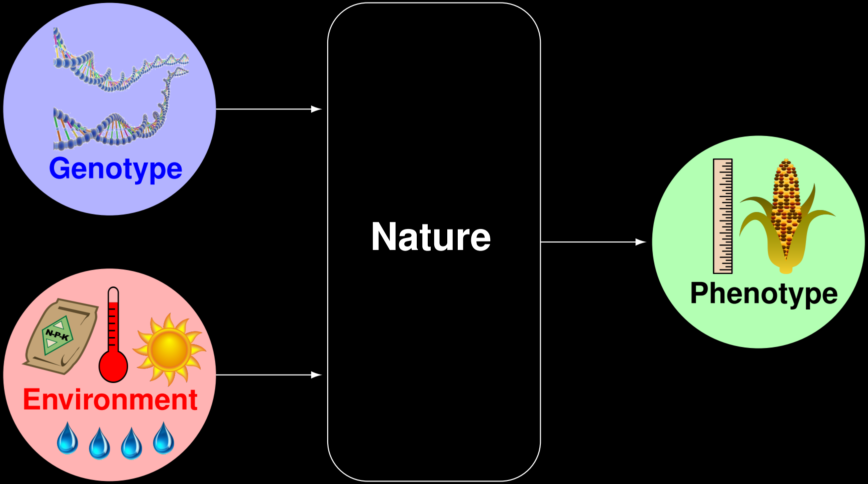
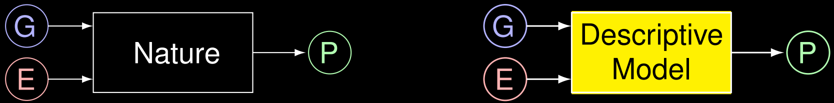
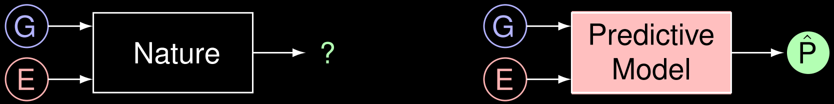
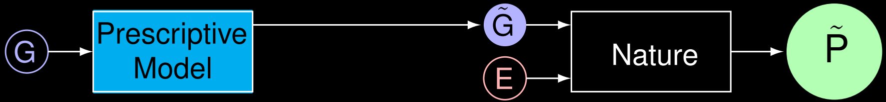

Genotype
Environment
N-P-K
Nature
Phenotype



Why did nature produce that phenotype?

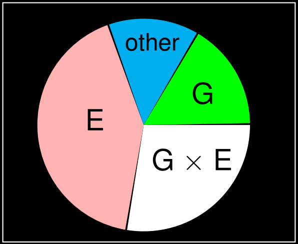


What phenotype will nature produce?



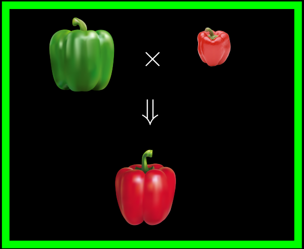
How to make nature produce that phenotype?

Descriptive | Predictive | **Prescriptive**



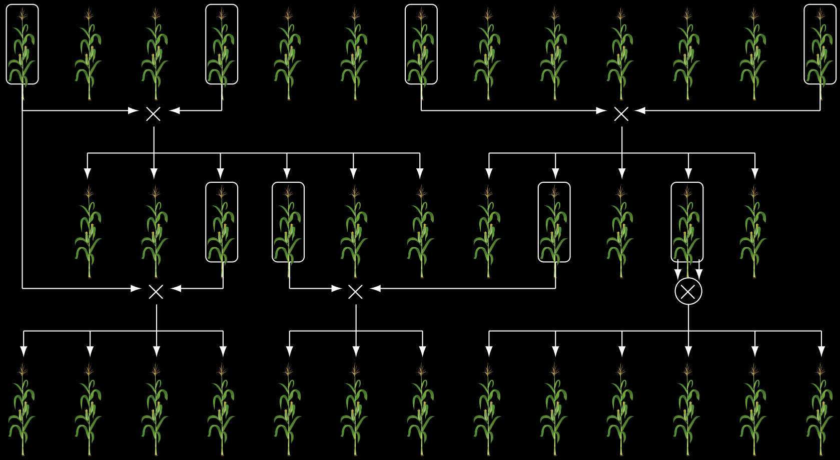
$G \times E$ Interactions

Yield Prediction

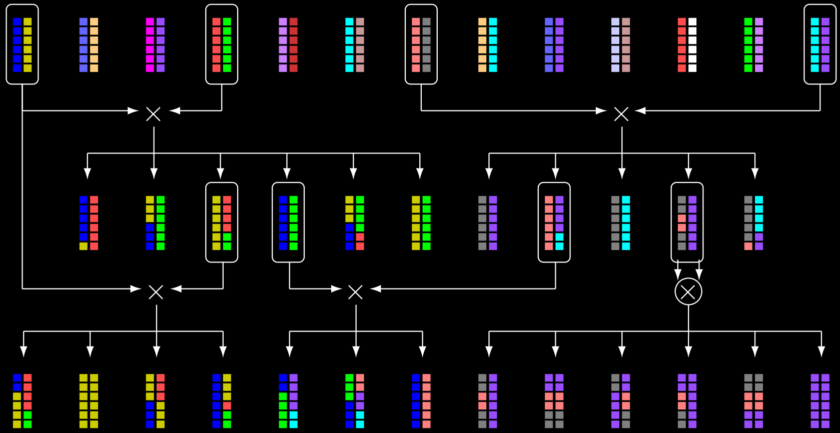


Genomic Selection

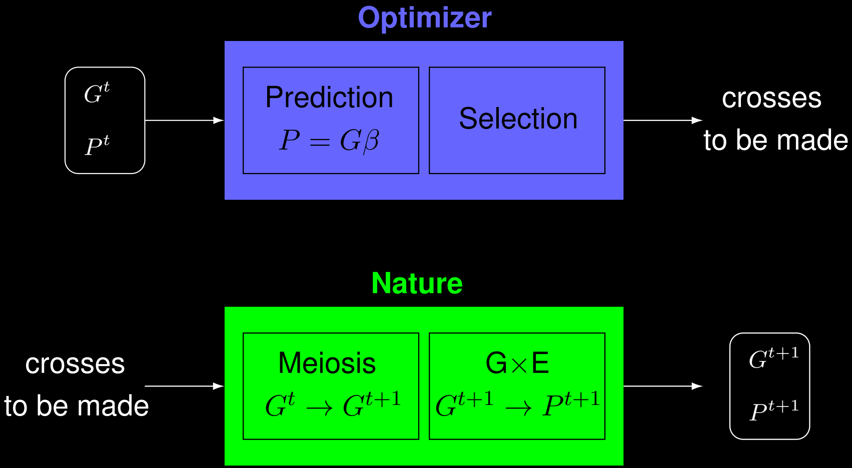
Breeding cycle



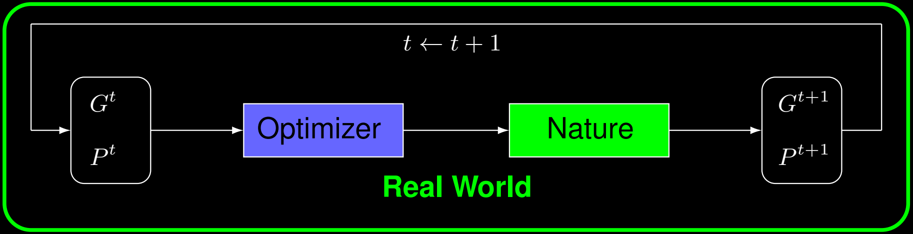
Genomic selection



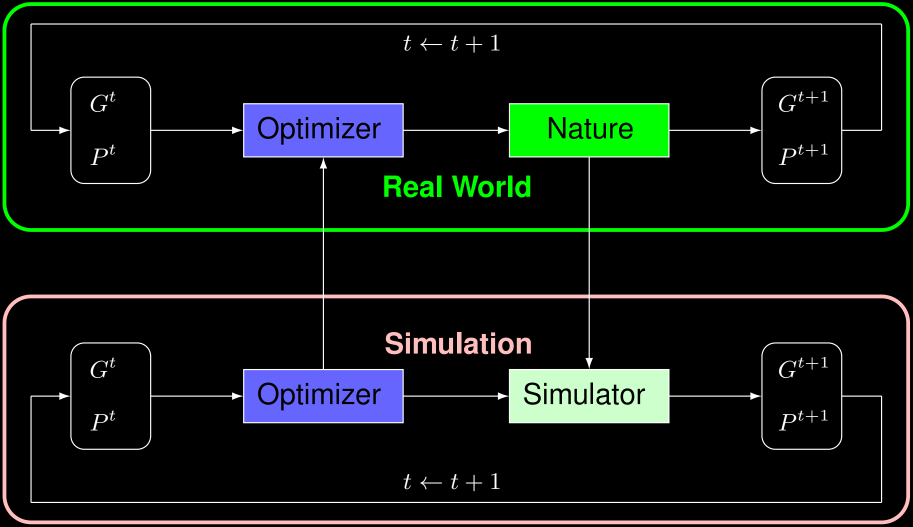
Optimizer and nature



Interactions between optimizer and nature



Optimizer vs. nature vs. simulator



Key messages

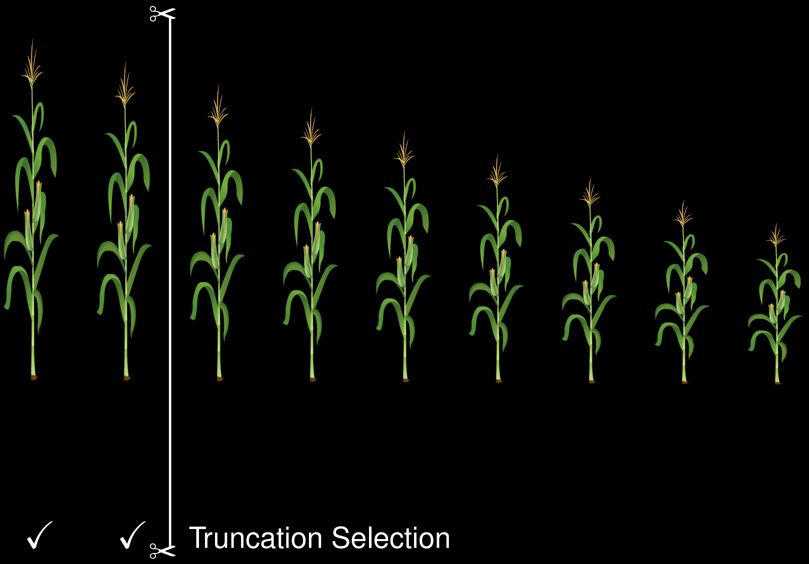
❶ Optimizer $=$ Genomic Prediction $+$ **Strategic Selection** $\neq$ Genomic Prediction $+$ Truncation Selection

❷ Simulator is crucial for Optimizer

Optimizers

	PS	CGS	OHV	OPV	LAS	LATB
selection	truncation short-term	truncation short-term	truncation long-term	group long-term	group long-term	group long-term
mating					✓	✓
time management					✓	✓
robust against prediction error						✓

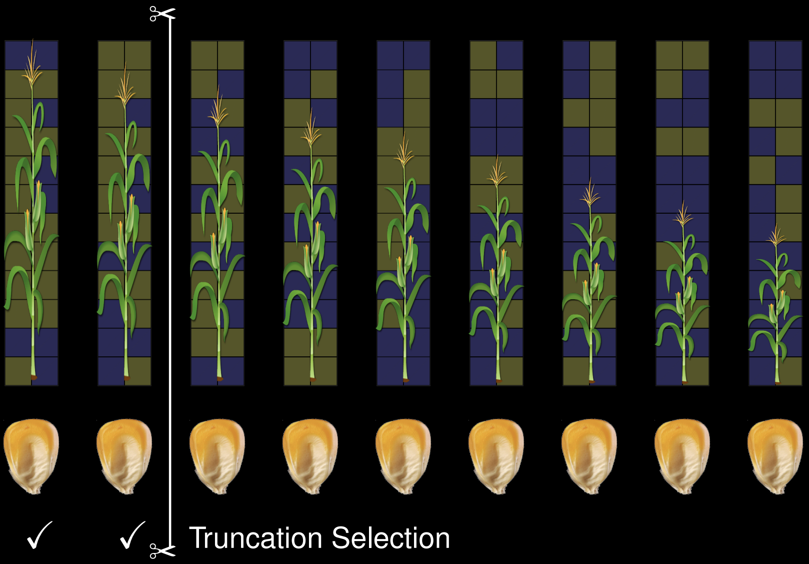
PS phenotypic selection



CGS conventional genomic selection

- **GEBV** (genomic estimated breeding value): Sum of additive genetic effects of all alleles [Meuwissen et al. 2001]
- Select individuals that have the highest GEBVs.
- **Pros:** Effective at achieving short-term genetic gains (verified by numerous experiments in plants and animals)
- **Cons:** Loss of long-term growth potential

CGS example



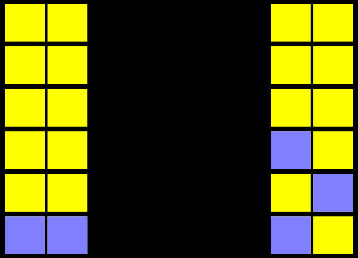
OHV optimal haploid value

- **OHV** (optimal haploid value): Best progeny from self pollination in the next generation [Daetwyler et al. 2015]
- Select individuals that have the highest OHVs.
- **Pros:** Emphasis on the potential of progeny (rather than achievement of the parents)
- **Cons:** Still a truncation selection

OHV example

favorable

unfavorable



GEBV	✓	
OHV		✓

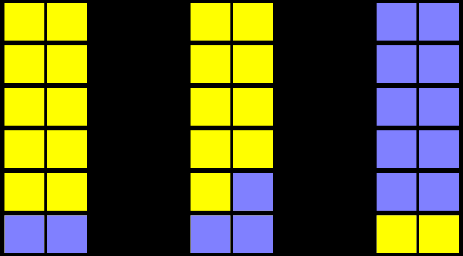
OPV optimal population value

- **OPV** (optimal population value): Best progeny of selected parents after multiple generations [Goiffon et al. 2017]
- Select a group of parents that have the highest OPV.
- **Pros:** Proposed complementarity based selection rather than truncation selection
- **Cons:** Ignores time constraints

OPV example

favorable

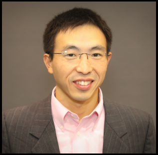
unfavorable



GEBV	✓	✓	
OHV	✓	✓	
OPV	✓		✓

Publication





HIGHLIGHTED ARTICLE
GENETICS | GENOMIC SELECTION

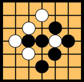
Improving Response in Genomic Selection with a Population-Based Selection Strategy: Optimal Population Value Selection

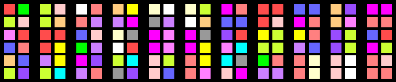
Matthew Goiffon,[*] Aaron Kusmec,[†] Lizhi Wang,[*,1] Guiping Hu,[*] and Patrick S. Schnable[†]
[*]Department of Industrial and Manufacturing Systems Engineering and [†]Department of Agronomy, Iowa State University, Ames, Iowa 50011

Deep blue (1996)

AlphaGo (2016)

Go vs. GS





States	Board positions, $\sim 3^{361}$	Population genotypes, $\sim 3^{4,000,000}$
Actions	Adding one stone to the board, ≤ 361	Selection, mating, resource allocation, $\sim 200^{40}$
Transition	Deterministic	Stochastic
Reward	Win or loss	Genetic gain

LAS

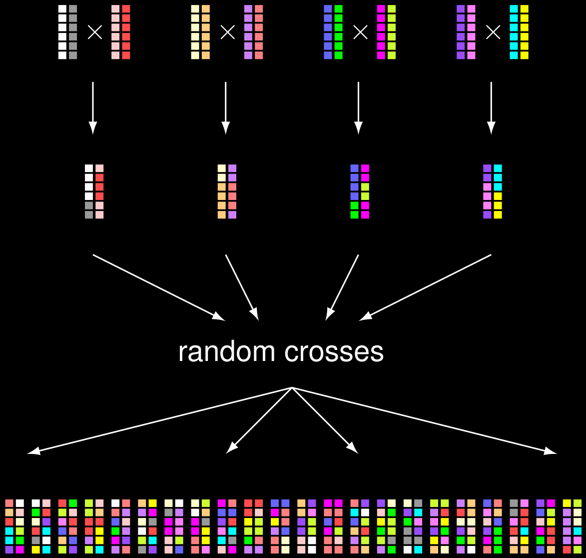
look ahead selection

generation t

generation $t+1$

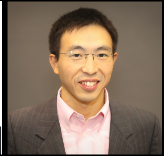
generation $\vdots$

generation T



Publication






G3 Genes | Genomes | Genetics

GENOMIC PREDICTION

Optimizing Selection and Mating in Genomic Selection with a Look-Ahead Approach: An Operations Research Framework

Saba Moeinizade,*,[1] Guiping Hu,* Lizhi Wang,* and Patrick S. Schnable†
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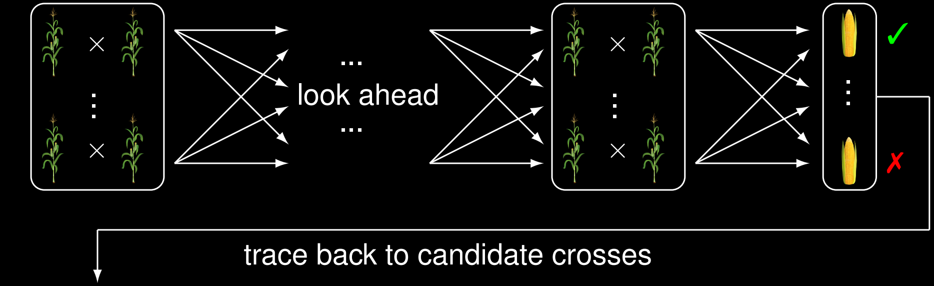
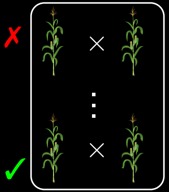
ORCID IDs: 0000-0001-7402-3385 (S.M.); 0000-0001-8392-8442 (G.H.); 0000-0002-5527-4047 (L.W.); 0000-0001-9169-5204 (P.S.S.)

LATB look ahead trace back

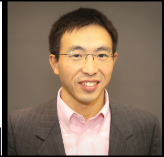




Differences between LATB and LAS

- LATB accounts for selection; LAS doesn't.
- LAS assumes accurate allele effects; LATB doesn't.
- LATB looks ahead one generation at a time;
  LAS looks directly at the final generation.

Publication

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OPEN

The look ahead trace back optimizer for genomic selection under transparent and opaque simulators

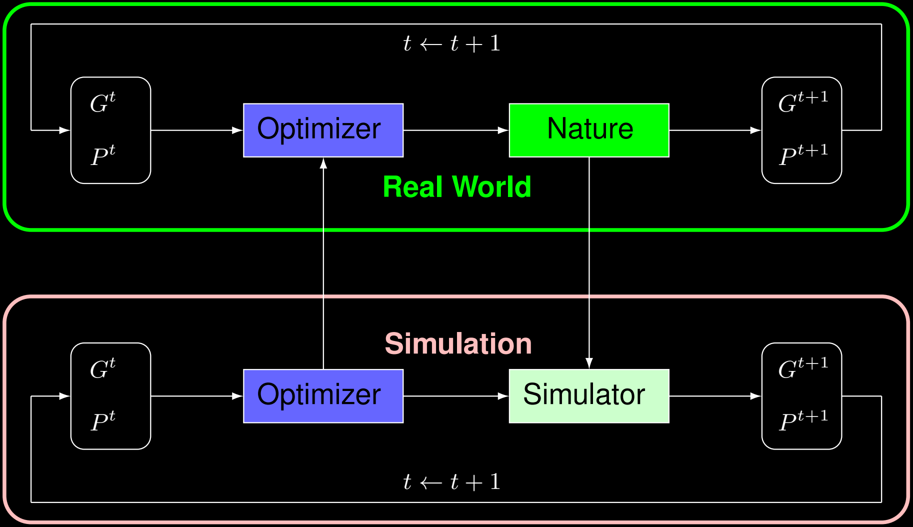
Fatemeh Amini, Felipe Restrepo Franco, Guiping Hu & Lizhi Wang✉

Key messages

❶ Optimizer $=$ Genomic Prediction $+$ **Strategic Selection** $\neq$ Genomic Prediction $+$ Truncation Selection

❷ Simulator is crucial for Optimizer

Nature vs. simulator



Transparent vs. opaque simulators

	Transparent	**Opaque**
G	G is the whole genome	G is a subset of the whole genome $\overline{G}$
β	β is the truth	True additive and non-additive effects, θ, of the whole genome are unknown
P	$P = G\beta + \epsilon$	$P = f(\overline{G}\|\theta) + \epsilon$

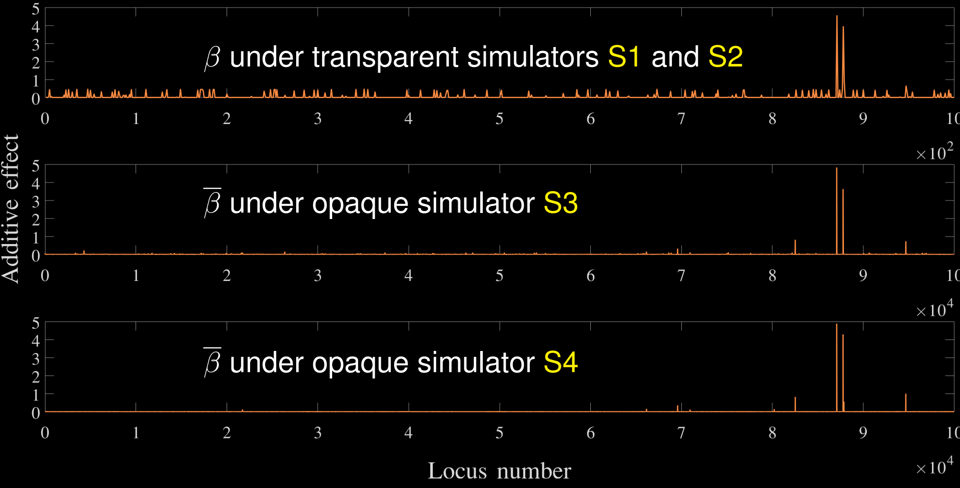
Q: How to make $\overline{G}$ and $f(\cdot|\theta)$?

A: Arbitrarily. The purpose is not to predict how nature behaves but to reveal how the optimizer interacts with an opaque nature.

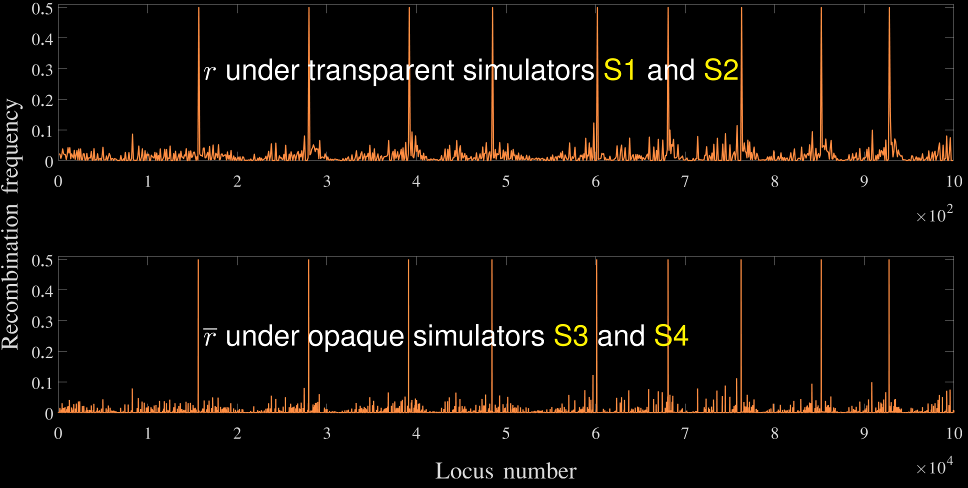
Four simulators

Simulator	Observed Genome	Whole Genome	Additive Effects	Dominance Epistases
S1	1,000	1,000	known	none
S2	1,000	1,000	unknown	none
S3	1,000	100,000	unknown	none
S4	1,000	100,000	unknown	unknown

Additive effects used in simulators



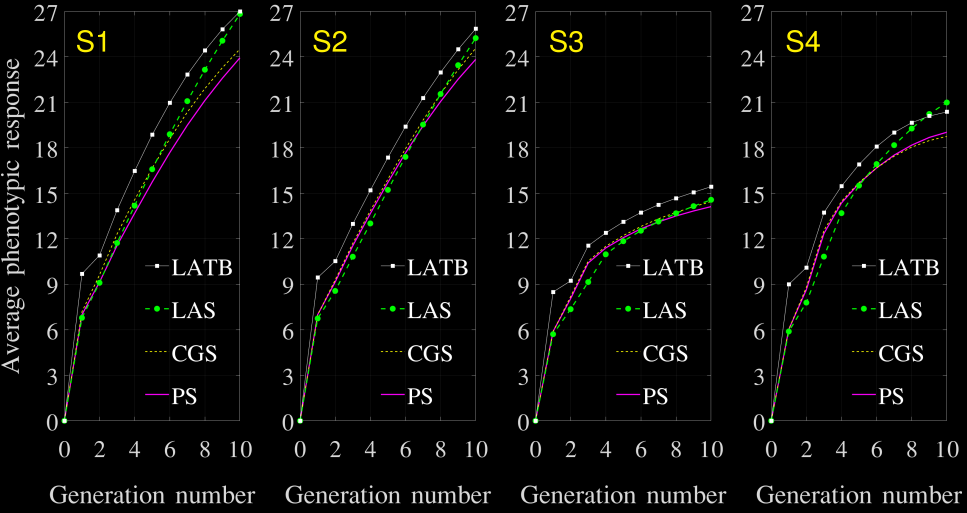
Recombination frequencies used in simulators



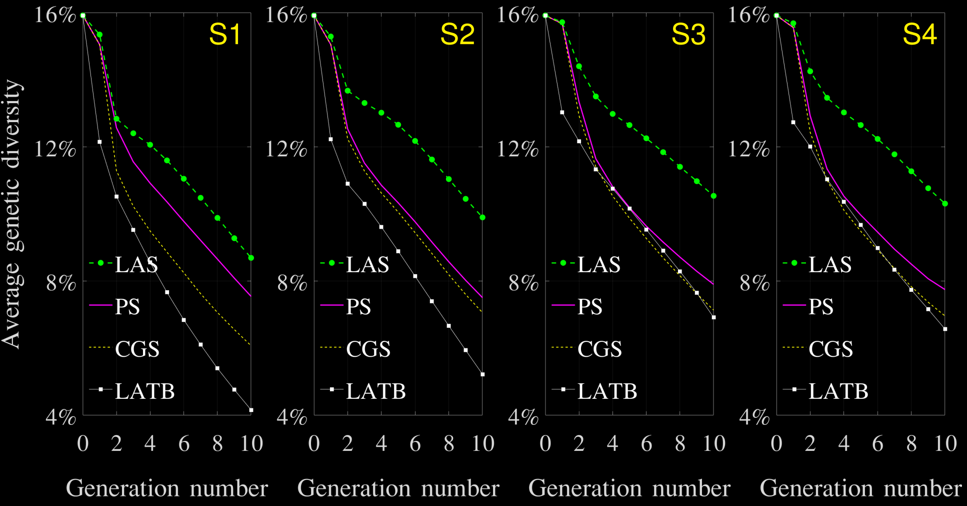
Four optimizers

Optimizer	Prediction
PS	none
CGS	one β from ridge regression
LAS	one β from ridge regression
LATB	multiple β's from ridge regression

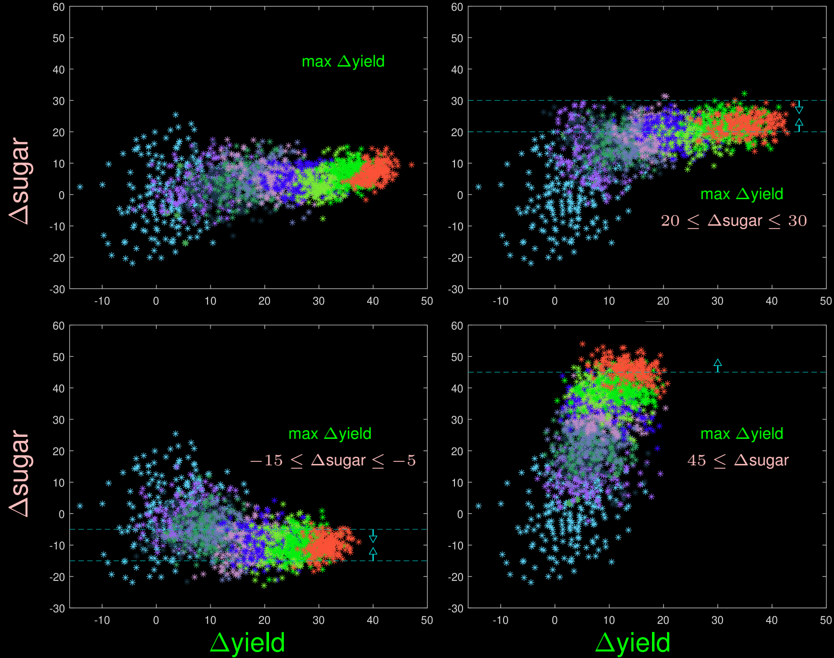
Results: phenotypic response



Results: genetic diversity (minor allele frequency)



Look ahead selection for multiple traits



Publication





GENETICS | GENOMIC PREDICTION

Multi-trait Genomic Selection Methods for Crop Improvement

Saba Moeinizade,[*] Aaron Kusmec,[†] Guiping Hu,[*,1] Lizhi Wang,[*] and Patrick S. Schnable[†]
[*]Department of Industrial and Manufacturing Systems Engineering and [†]Department of Agronomy,
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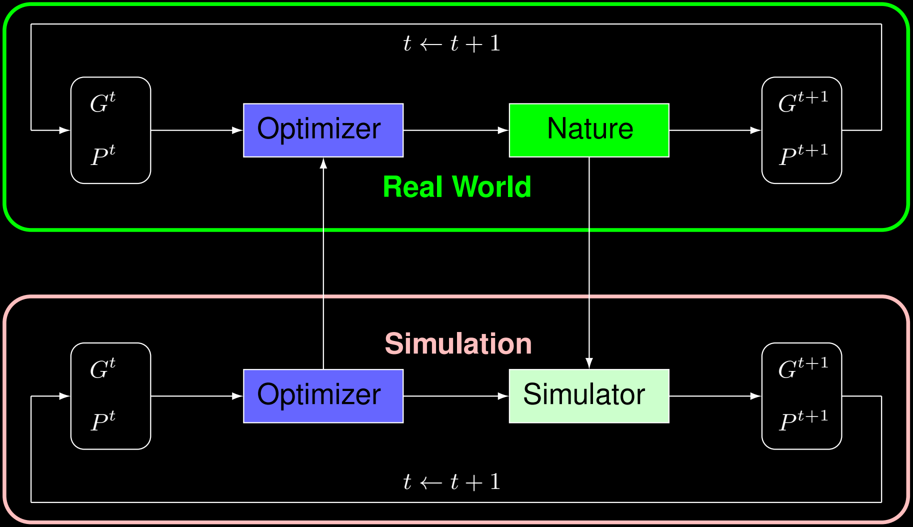
Take home message



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FFAR
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and Agriculture Research

DMDII
a UI LABS Collaboration

IOWA STATE UNIVERSITY
Plant Sciences Institute

PSERC

Center for e Design

BASF
We create chemistry

syngenta

Thank you

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