



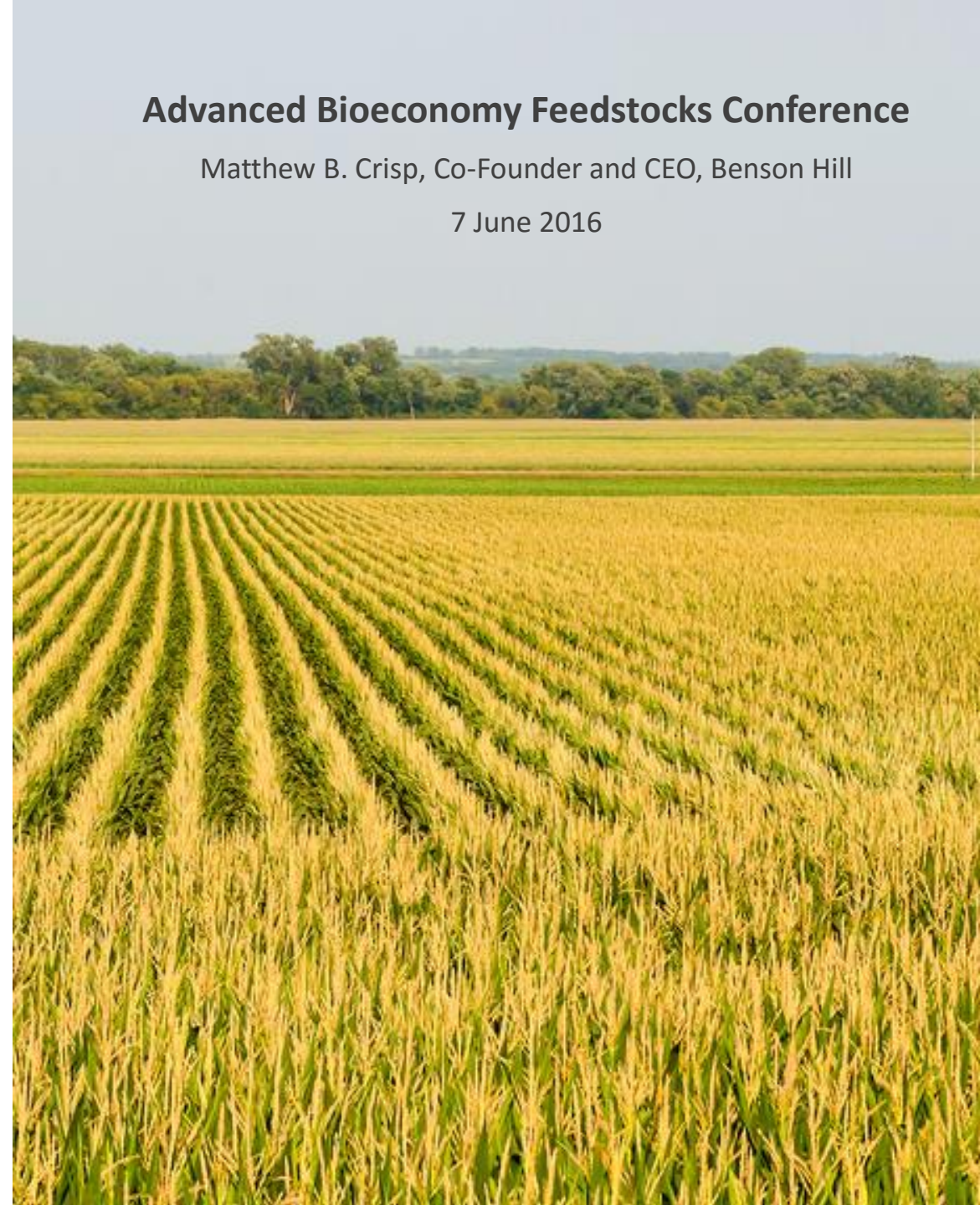
*Let's advance agriculture
together*

**UNLOCKING THE GLOBAL GENETIC POTENTIAL
OF PLANTS TO BENEFIT PEOPLE AND OUR PLANET**

Advanced Bioeconomy Feedstocks Conference

Matthew B. Crisp, Co-Founder and CEO, Benson Hill

7 June 2016



- Agriculture technology company employing cloud biology to improve crop performance and empower innovation throughout the agriculture value chain
- Our Purpose: to make plants to meet the world's food and energy demands
- 44 team members with operations in St. Louis, MO and RTP, NC

Sustainability

Developing plant-based solutions to address our greatest global challenges

Improving food and nutrition security



Enhancing resource use efficiency

Combining cloud computing, big data analytics and plant biology expertise



Innovation

Empowering a new era of innovation through Cloud Biology

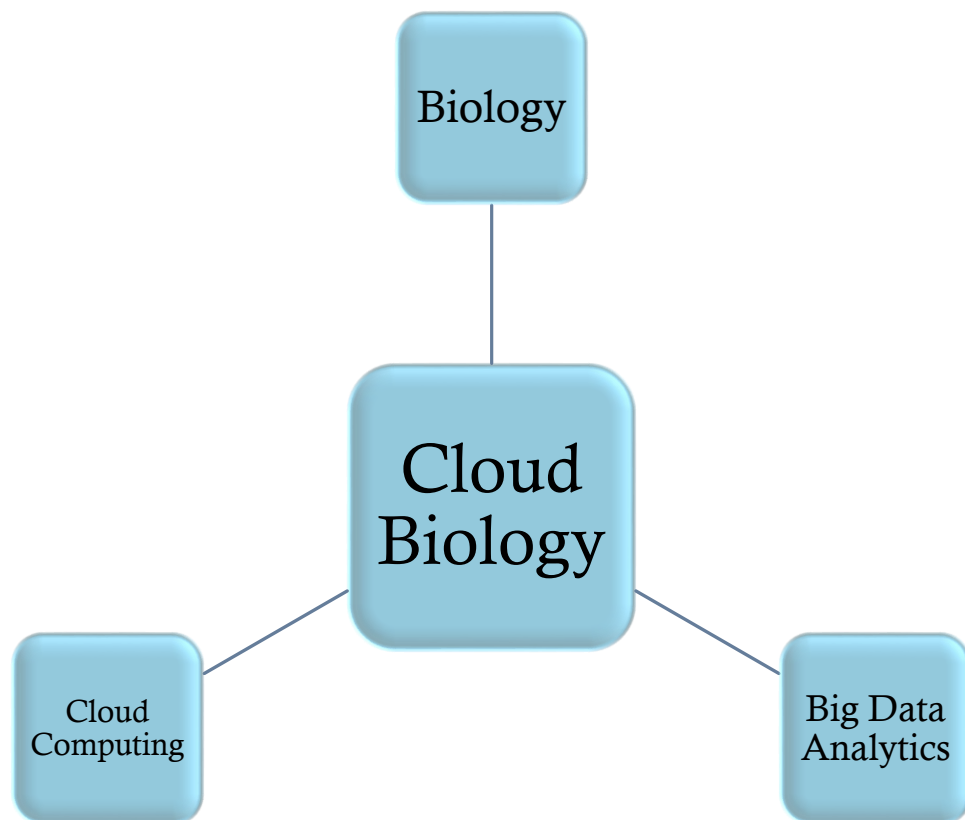
Collaboration

Working with our partners, sharing in their risk and reward



Understanding and accelerating our partner's R&D programs





NEWS

Cloud Biology in Agriculture: Taking Big Data to a New Level

From AgFunder News



What is Cloud Biology?

The convergence of big data analytics and cloud computing with biological expertise is greatly accelerating innovation in many industries, and most recently in agriculture. The combination of these various disciplines represents the foundation of Cloud Biology, an emerging field that is transforming not only what agricultural challenges we can tackle through innovation, but who is empowered to innovate.

Sequencing, genotyping, and phenotyping costs have tumbled in recent years, and at the same time, we continue to witness dramatic increases in both computing power and accessibility. Thanks to [AWS](#) and others, gone are the days of needing an onsite system admin to build a technology business. Data can be stored, accessed, and analyzed at scale in the cloud by even entry-level users.

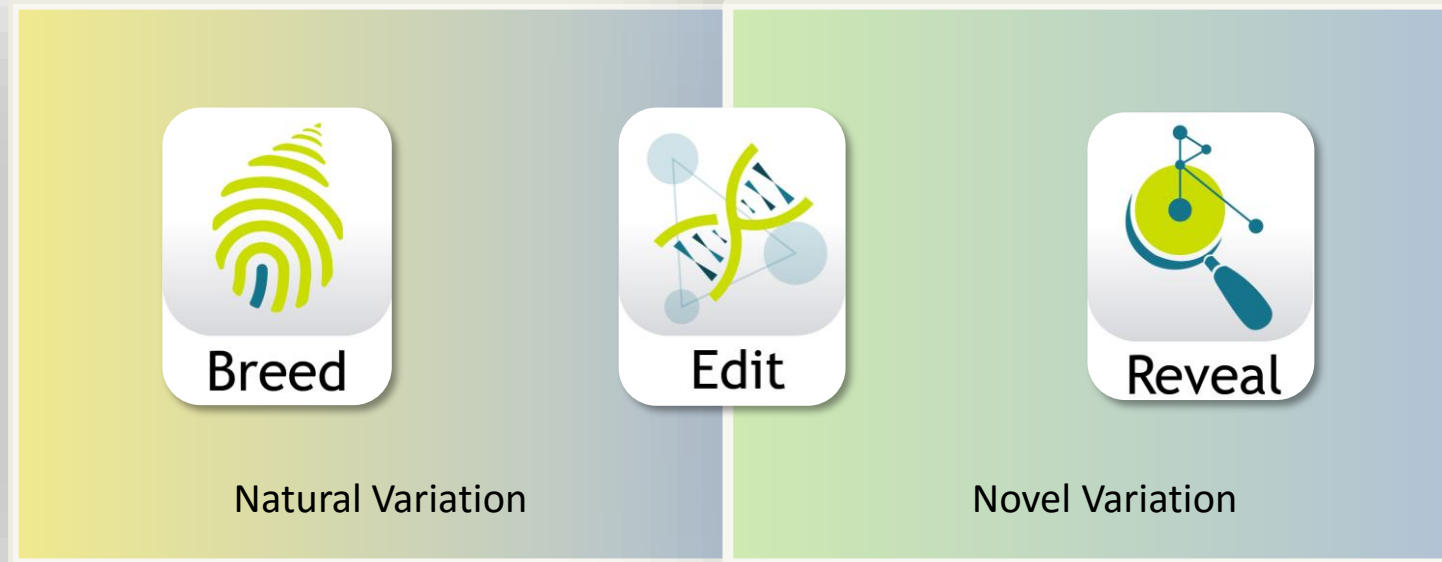
Couple this with rapidly improving analytics and with biology – that is, actually implementing outputs from a machine learning engine, then ground-truthing results and delivering superior products – and this defines the potential of Cloud Biology. How much is undertaken “in the cloud” – or virtual to the user – will evolve at different rates in different verticals over time. Suffice it to say that we are at the threshold of realizing this next generation of innovation, even in complex systems like plants.

Concepts of Cloud Biology in action

The concepts that embody Cloud Biology are not new. One element – virtualization, or complete outsourcing of program execution – has successfully been realized in drug development. After large-scale pharmaceutical research underwent significant contraction more than a decade ago, a network of capable CROs (contract research organizations) and CMOs (contract manufacturing organizations) emerged. Through economies of scale, shared risk models, and

Harnessing global genetic potential with CropOS™

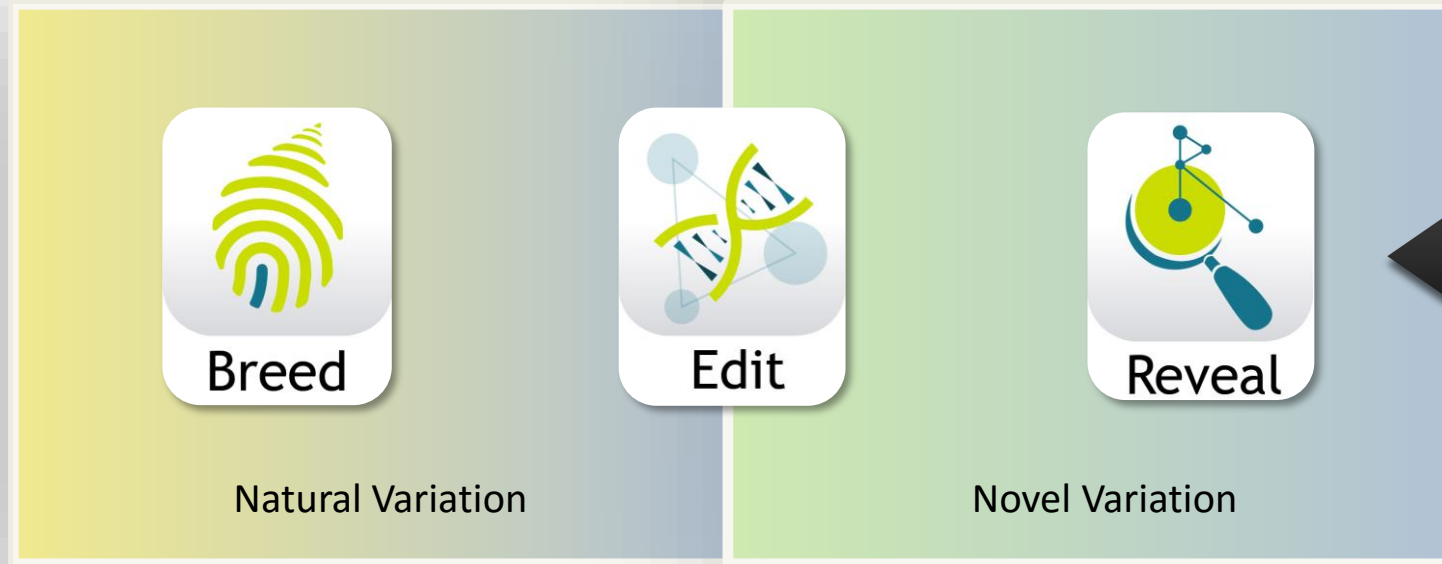
across the continuum of breeding, genome editing, and trait development



CropOS™

Harnessing global genetic potential with CropOS™

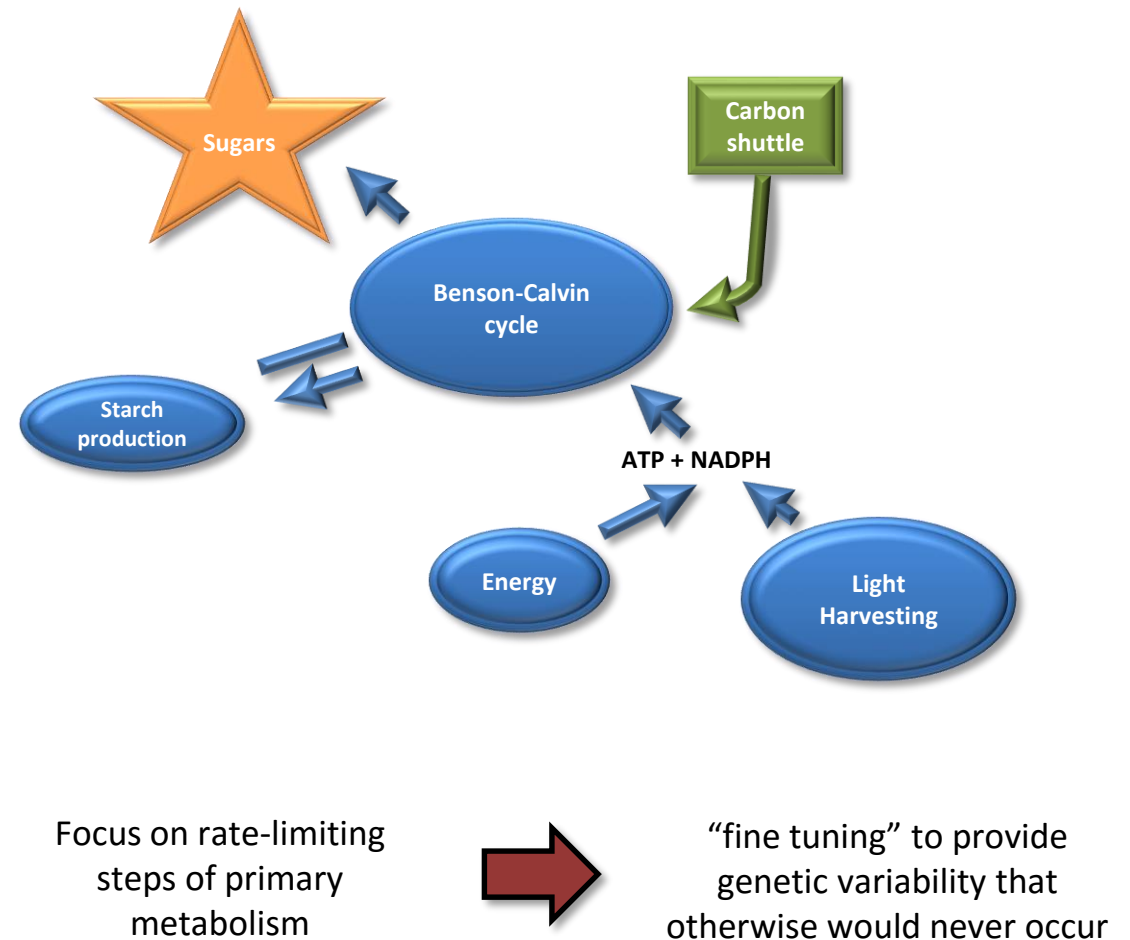
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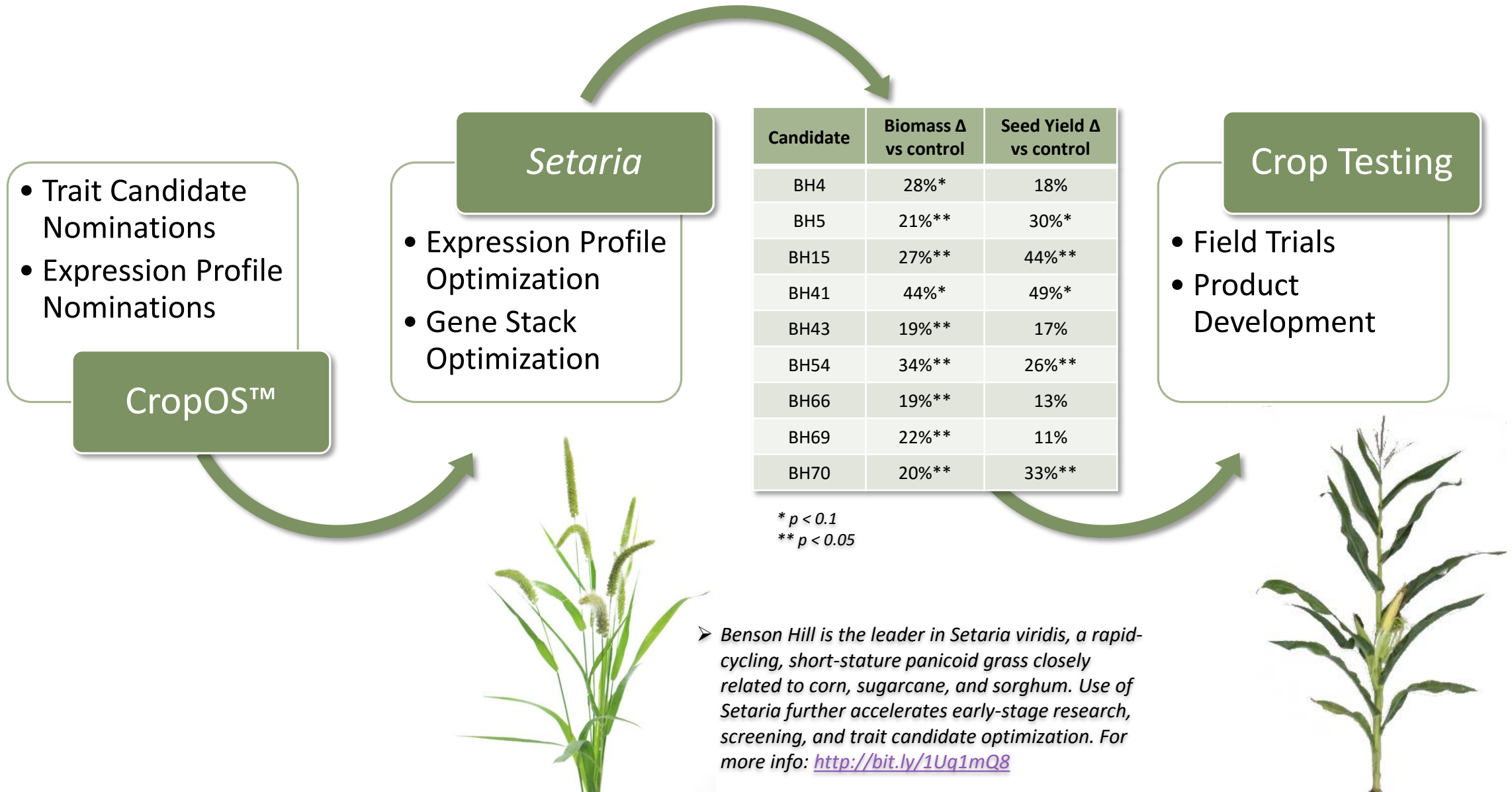
CropOS™

Use Case: identify trait leads to increase feedstock biomass

- Target: photosynthesis, the most promising target to increase crop productivity
- Approach: utilize **CropOS™** to identify promising trait candidates
- Testing platform: *Setaria viridis*, the crop model system of choice for C4 grasses, e.g. sorghum
- Threshold: >15% increase in biomass

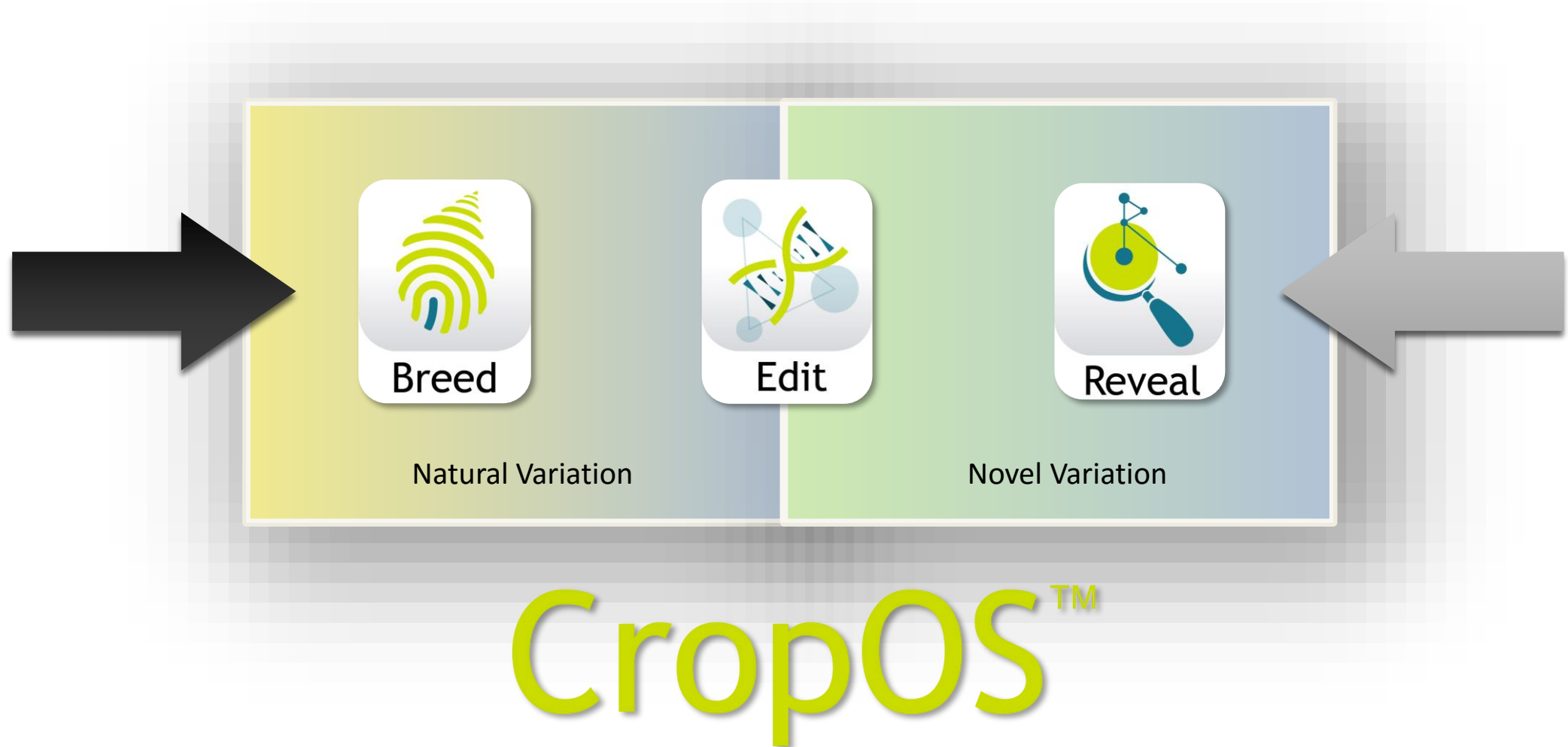


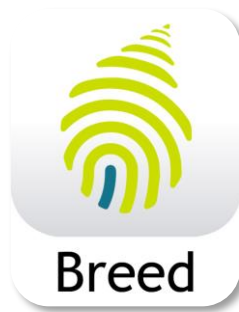
Result: hit rate >10X industry average



Harnessing global genetic potential with CropOS™

across the continuum of breeding, genome editing, and trait development





MANAGE PHENOTYPES

MAP NETWORKS

ANNOTATE

PREDICT TRAITS

IDENTIFY LINES

CropOS™

8 Crops

>6000 lines

>30M SNPs

8000 CNVs

Developmentally staged transcriptomes

Co-Expression gene network models

Curated photosynthesis gene dbase

Tissue-specific transcriptomes

Gene prediction models

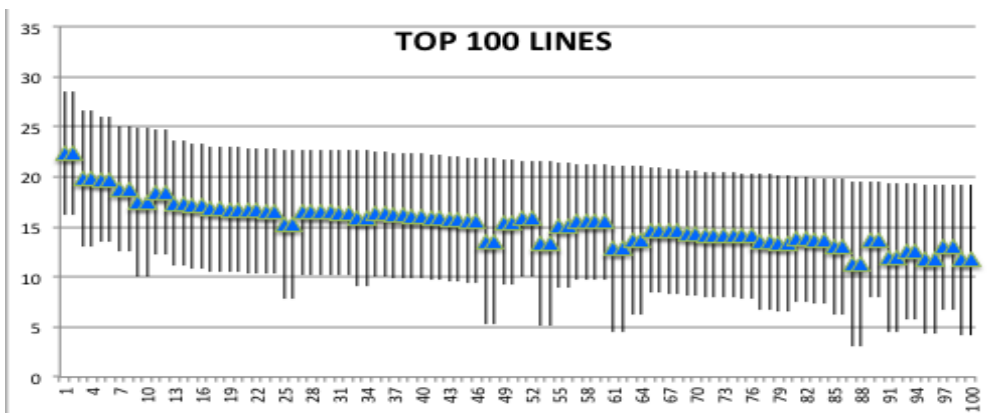
Public and private transcriptomes

BREED, *powered by CropOS™*

a decision support platform for line advancement and cross selection

Numeric accuracy of Genomic Selection is poor

With permutation, computational jackknife, correct distillation of analytics, can still select optimal decisions



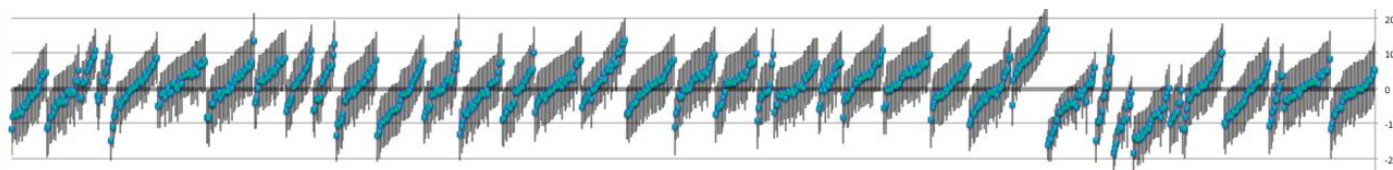
✓ Faster cycle time

✓ More robust selection

Possible crosses greatly exceed any breeding throughput

Can identify probable range or cross outputs, guide users on which crosses to execute based on desired outcome:

- Cross that will create the most variability (early stage)
- Cross that is most likely to generate superior progeny (late stage)

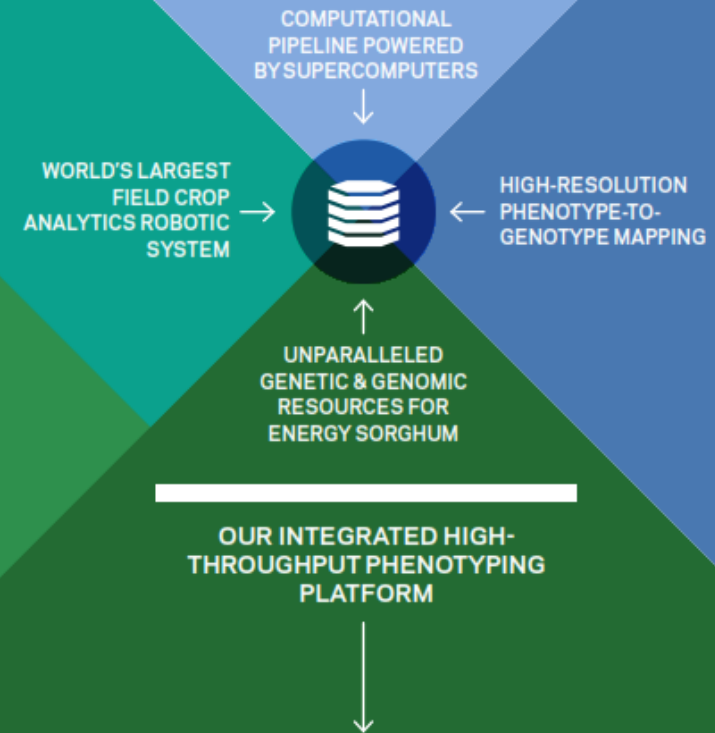


✓ Better product, faster to market



The Transportation Energy Resources from Renewable Agriculture Phenotyping Reference Platform (TERRA-REF) is a national high-throughput phenotyping platform that aims to revolutionize plant breeding.

Our goal is to accelerate breeding and the commercial release of high-yield bioenergy sorghum hybrids.



TERRA-REF will generate and make public an unprecedented volume of high-resolution time-series crop image data that can be used to train predictive algorithms and to screen diverse germplasm collections for the genetic sequences that encode commercially relevant sorghum traits.

Sorghum for Bioenergy Production

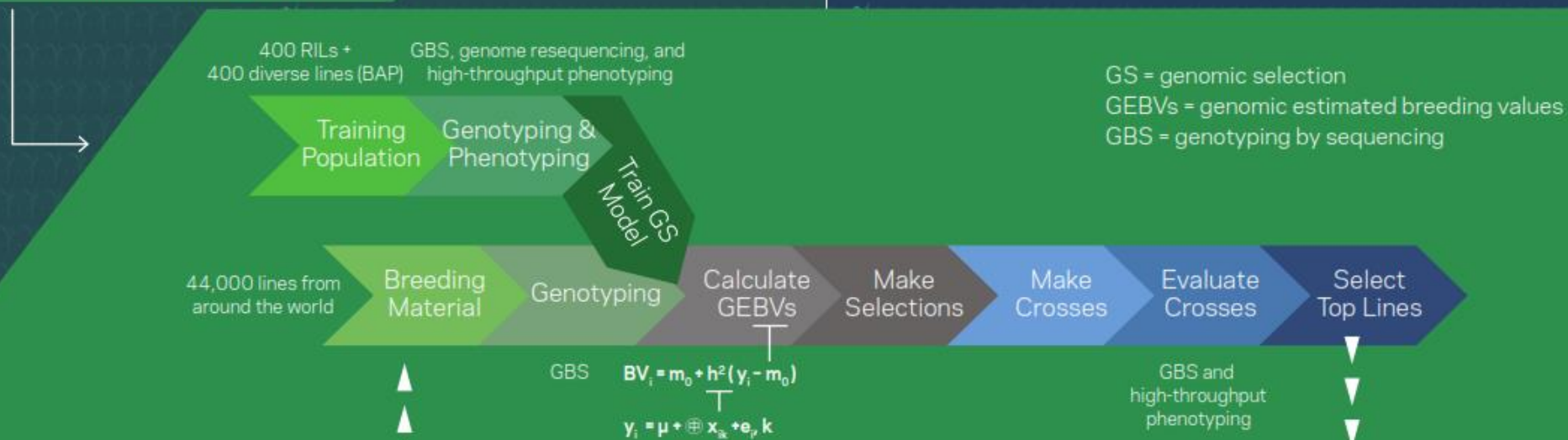


The use of plant biomass for fuel and power is a central component of our nation's strategy to reduce our dependence on oil. Sorghum is positioned to become the premier source of cellulosic biomass in the U.S.

- Adapts easily to diverse environments.
- Requires very little fertilizer.
- Has high biomass potential.
- Compatible with row crop production.
- Grows rapidly in a variety of climates.
- Grows well in marginal substrate, including saline and aluminum-toxic soils.
- Is heat and drought tolerant.
- Offers significant potential for genetic improvement.

These factors, coupled with the size and diversity of the germplasm collection (~44,000 lines), make sorghum an ideal species for biofuel production.

How do we identify the best sorghum lines for breeding from a germplasm collection of 44,000 lines?



TERRA-REF combines advanced sensing with novel analytical approaches to accelerate sorghum breeding

Breeding is a numbers game. Advances are limited by the speed and cost at which phenotypes (i.e., plant traits) can be accurately and precisely measured. TERRA-REF will use advanced cutting-edge camera and sensor technologies, novel algorithms for image analytics, and supercomputers to measure crop growth and development efficiently, accurately, and quantitatively under different environmental conditions. An array of cameras and imaging sensors will provide an enormous data stream (2-5 TB per day) with unprecedented image resolution (less than 1 square centimeter).

We will develop novel analytical approaches to exploit this impressive volume of crop data, including state-of-the-art sensor processing algorithms to extract digital traits from image data and machine learning algorithms to predict biomass potential and identify elite germplasm from mid-season datasets. Data processing workflows will be powered by supercomputers.

We will resequence the genomes of ~400 diverse sorghum lines to measure the landscape of genetic variation in sorghum and provide whole-genome sequences for trait association mapping. These data will be leveraged to map traits to the small genomic regions that encode them. Our innovative approach will allow us to rapidly identify new genetic combinations for use in breeding and commercial production programs.

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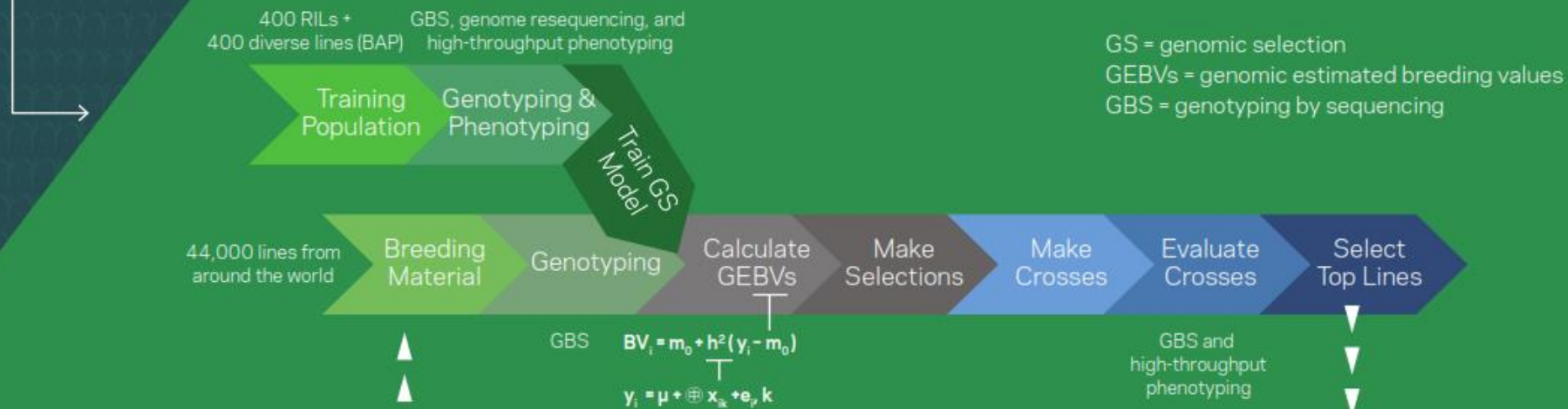
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DISCOVERY | COMMUNITY | IMPACT



CHANGING WHAT'S POSSIBLE

BENSON • HILL
BIOSYSTEMS

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mcrisp@bensohillbio.com

THANK YOU

