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Collaborative Research on Sorghum and Millet
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2022 ANNUAL REVIEW MEETING

March 21-25, 2022

Virtual

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Collaborative Research on Sorghum and Millet

Durable adaptation to aphid and drought for smallholder sorghum in the Americas

Gael Pressoir, Quisqueya University

Jean Rigaud Charles, Carl Carl VanGessel, Brian Rice,
Kristen Johnson ,Yvens Cheremond, Geoff Morris, and many more…..

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INTRODUCTION

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Some of our priorities in sorghum for the coming years

- **Improve transferability for the resistance to aphids to other programs (molecular and physiological characterization) (SMIL)**
- **Development of photoperiodic (*gwo pitimi*) SA resistant varieties (SMIL)**
- **Enhanced drought tolerance (SMIL)**
- Integration of GS and physiological breeding for yield stability (CACCIA - ILCI)
- Development of new SA resistant multipurpose sorghum (CACCIA - ILCI)
- Development of new SA resistant semi-dwarf sorghum for intensification (CACCIA - ILCI, Brana *Pitimi Lakay*)
- Sustainable Intensification and appropriate mechanization (WKKF - Kellogg Foundation, Haiti's Central Bank - BRH)
- Improved seed systems (ILCI)
- Product development (extrusion - instant *Ju Kole*) (WKKF - Kellogg Foundation, Haiti's Central Bank - BRH)

The 2013 new North American Sorghum Aphid biotype seems to be here to stay…

- Could it spread beyond the Americas (?)
- Farmers in Central America have to use large amounts, and multiple applications, of **Neonicotinoids** (**Imidacloprid**) - exemple in mexico
- Still some outbreaks in the US

Resistant versus susceptible varieties

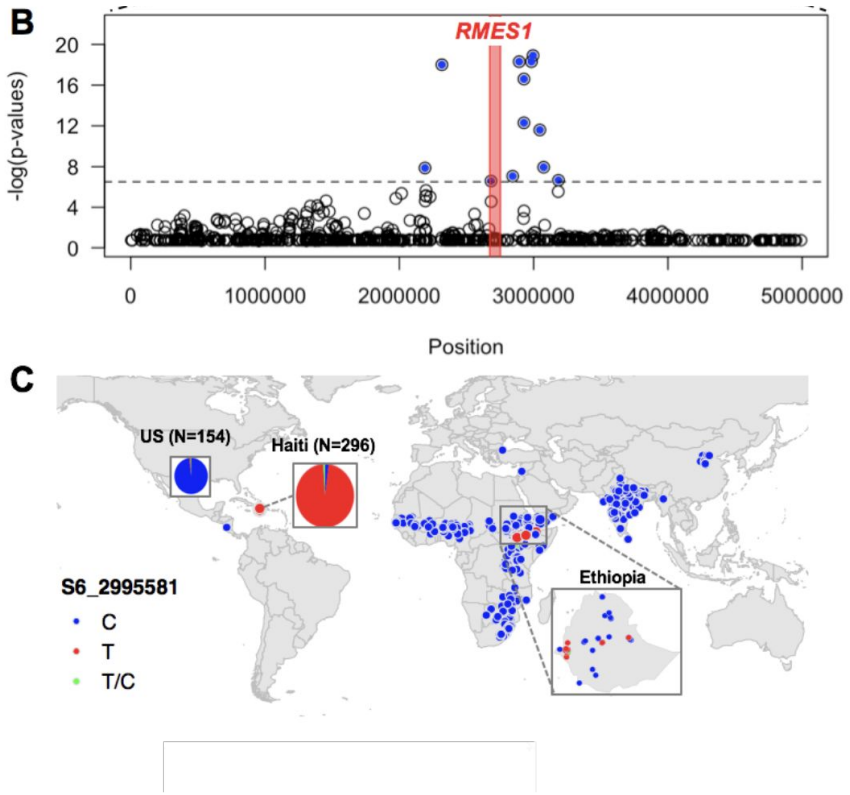
The Chibas breeding program has been successful breeding for high levels of SA resistance

A localized selective sweep

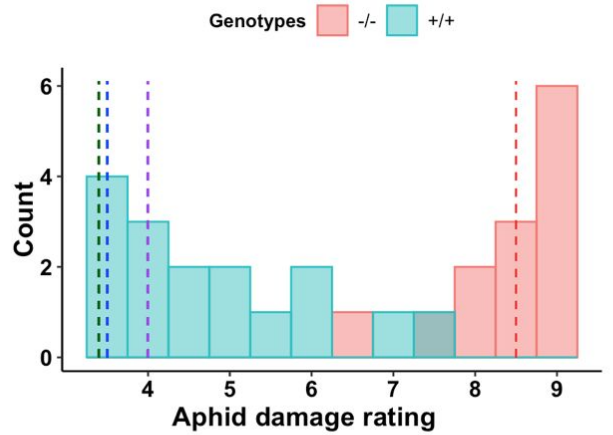
The Chibas population went through a selective sweep at specific locations including the RMES1 locus on Chr 6

Muleta, *et al* (2022). The recent evolutionary rescue of a staple crop depended on over half a century of global germplasm exchange *Science Advances*, Vol 8, Issue 6

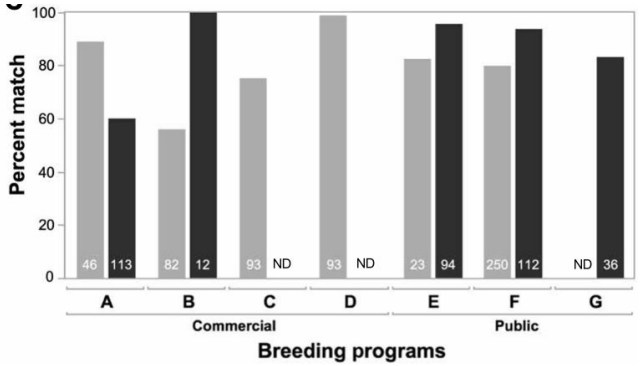
Chibas' SCA resistance is due to a rare allele from Ethiopia:



KASP marker predicts resistance:



Across Africa, US (private & public), Haiti:



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Global sorghum aphid resistance relies on one source

Carl VanGessel
Jean Rigaud Charles, Brian Rice
Geoff Morris, Gael Pressoir, and many more…..

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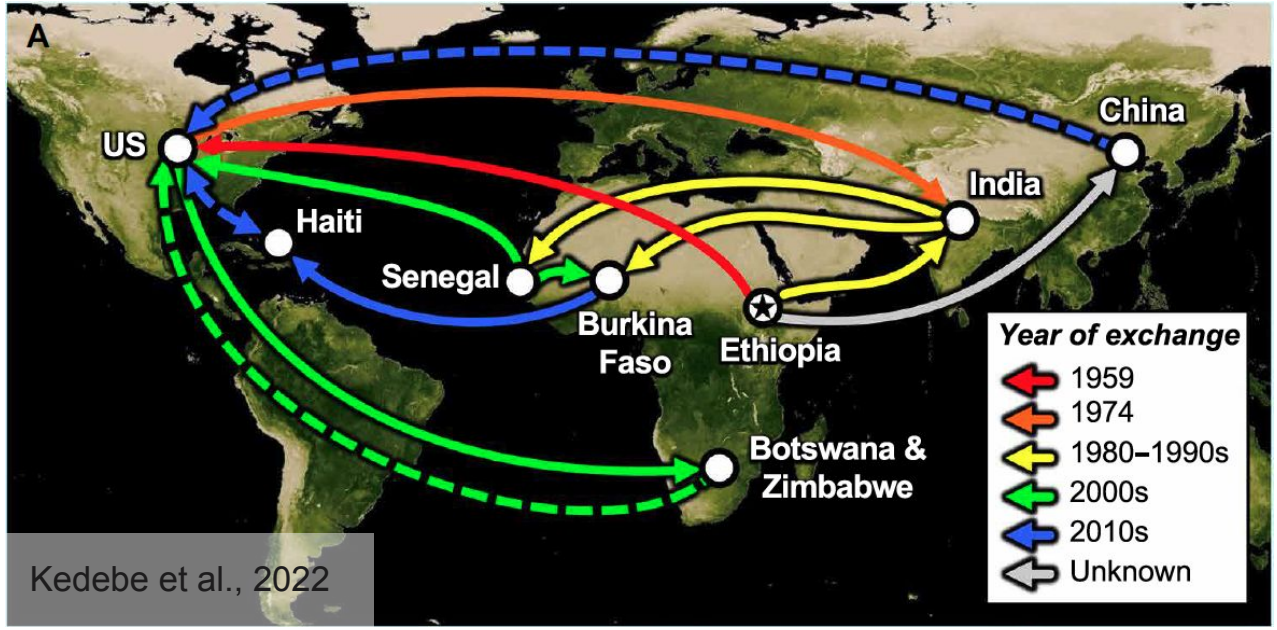
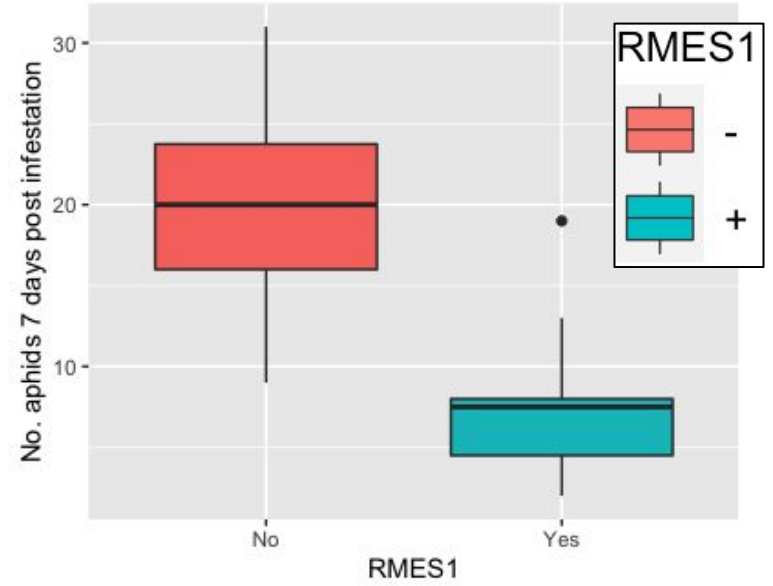
Global sorghum aphid resistance relies on one source

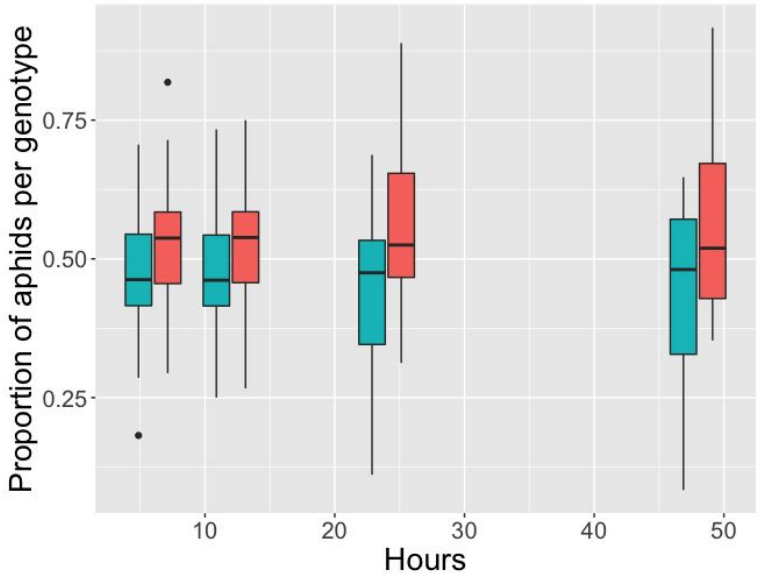
- *RMES1* is the only known source of major resistance to sorghum aphid (Wang et al. 2013, Muleta et al. 2022)
- The phenotype and mechanism are important for the durability of each resistance source.
- Near-isogenic lines (NILs) were developed to test hypotheses on the phenotype and mechanism.



RMES1 deters aphid feeding & slows aphid reproduction

- SA has higher reproduction on plants without *RMES1* when given no choice of feeding
- SA prefers plants without *RMES1* when given choice between genotypes
- Conclusion: *RMES1* is likely imposing strong selection on sorghum aphid globally — risk of biotype shift?



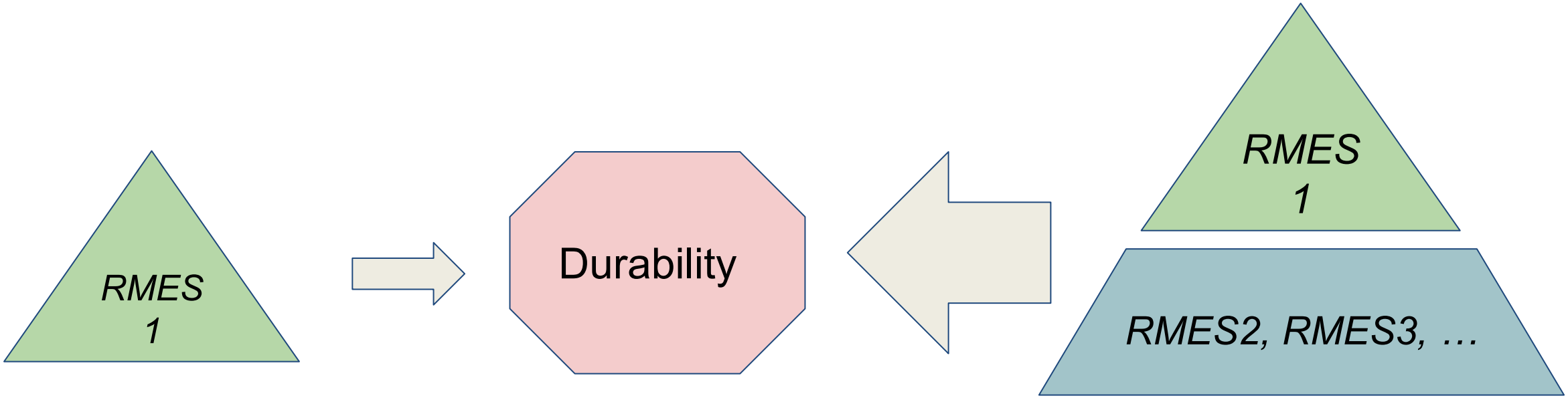


RMES1 mechanism is important for developing durable sorghum aphid resistance

- Not all mechanisms of resistance are equal

  "Gene-for-gene" resistance is strong but can quickly be overcome

- Mechanisms which act in the same pathway do not increase durability when "stacking" sources of resistance in gene pyramids



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Identifying Additional SA Resistance QTL

Brian Rice
Jean Rigaud Charles, Carl VanGessel
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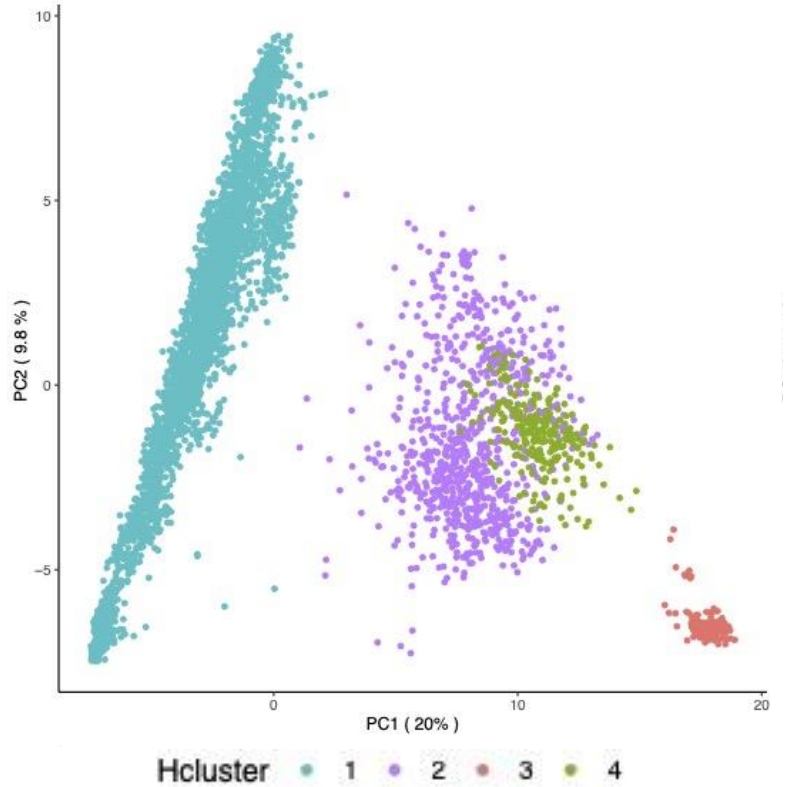
Identifying Additional SA Resistance QTL

Université Quisqueya Breeding Program

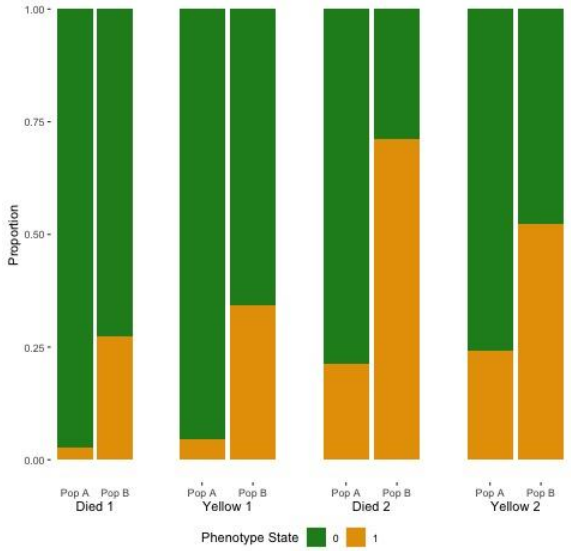
Pop A (cluster 1) Main Population - Fixed for *RMES1*

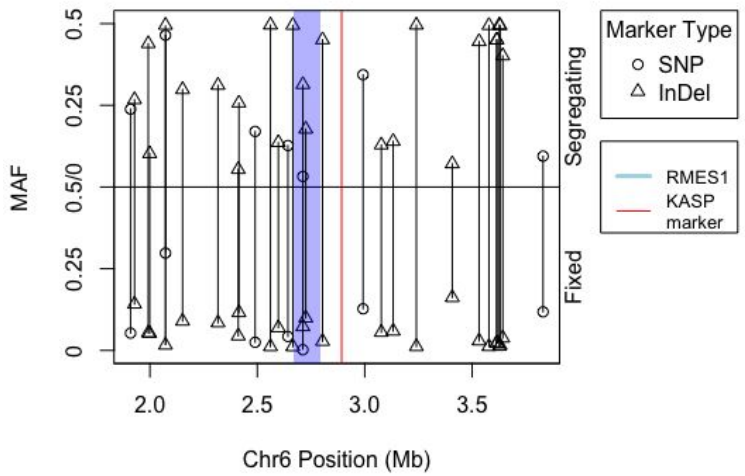
Pop B (clusters 2,3,4) F2 Populations created by crossing main breeding lines with novel lines

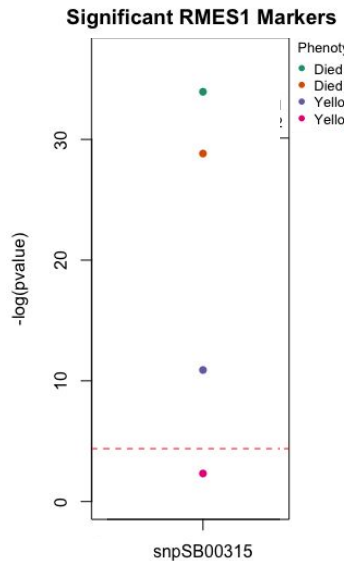


Pop B is segregating

- Segregating for SA Phenotypes
- Segregating for *RMES1* Genotype
- Significant KASP Marker

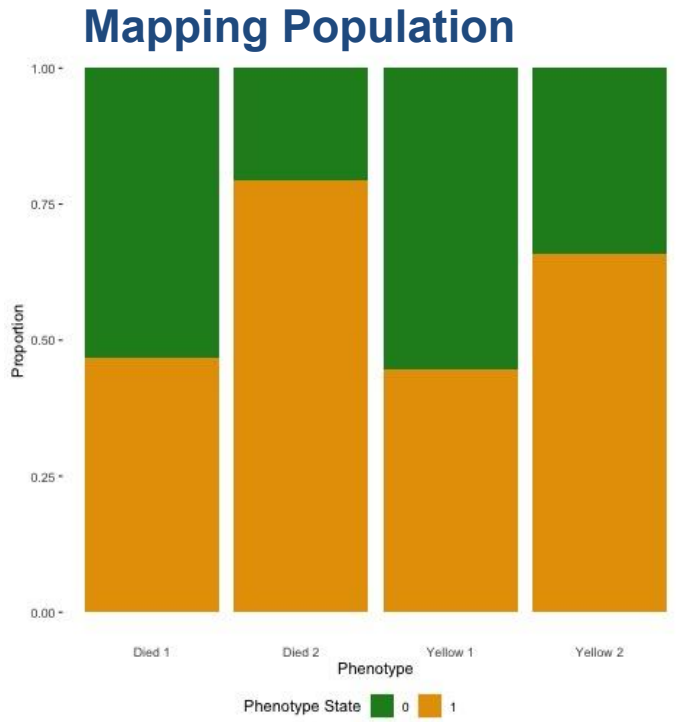


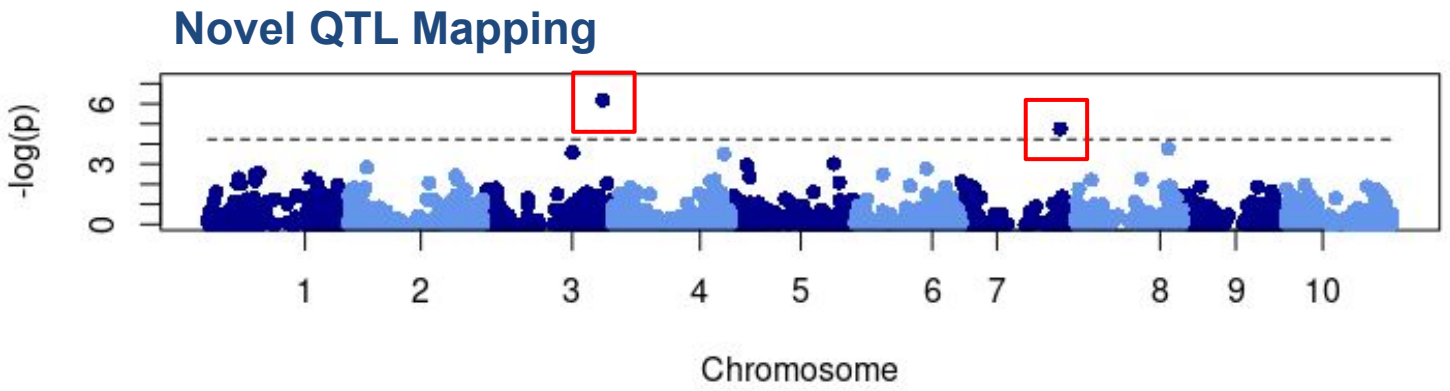




Mapping Population Created From Breeding Program

- MAS identified *RMES1* - lines
- Remaining lines are segregation for phenotype but not genotype
- Statistical Analysis Identifies regions linked to remaining phenotypic variation
- Novel QTL identified to increased resistance in main breeding program





Breeding Program Design to Identify and Incorporate Novel QTL

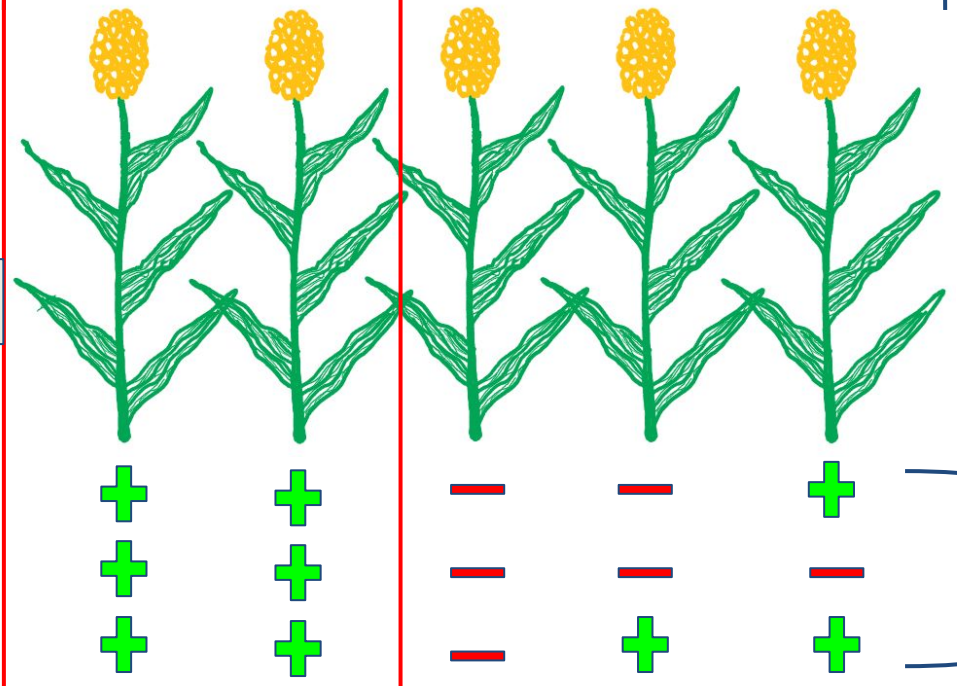
Fixed Ideotype
- Ex: height, maturity, local pest and stress resistance

Genomic Selection

Recurrent Selection Population

Novel Germplasm
- Diverse Landraces
- Elite Lines from Other Breeding Programs

F2 Population



Advantages

- Bring in more yield + QTL
- Screen Novel Germplasm For Ideotype
- Identify Novel QTL

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Resistance to SA is NOT MONOGENIC

Gael Pressoir

Jean Rigaud Charles, Carl Carl VanGessel, Brian Rice, Yvens Cheremond,
Geoff Morris, Gael Pressoir and many more…..

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RESULTS - Objective 1

- Additional QTLs can be detected in main population
- SA resistance is highly heritable in main population (that is fixed for RMES1)
- We have confirmed importance of RMES1 in a new population (photoperiodic)

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A model for Sorghum Aphid (SA) Resistance

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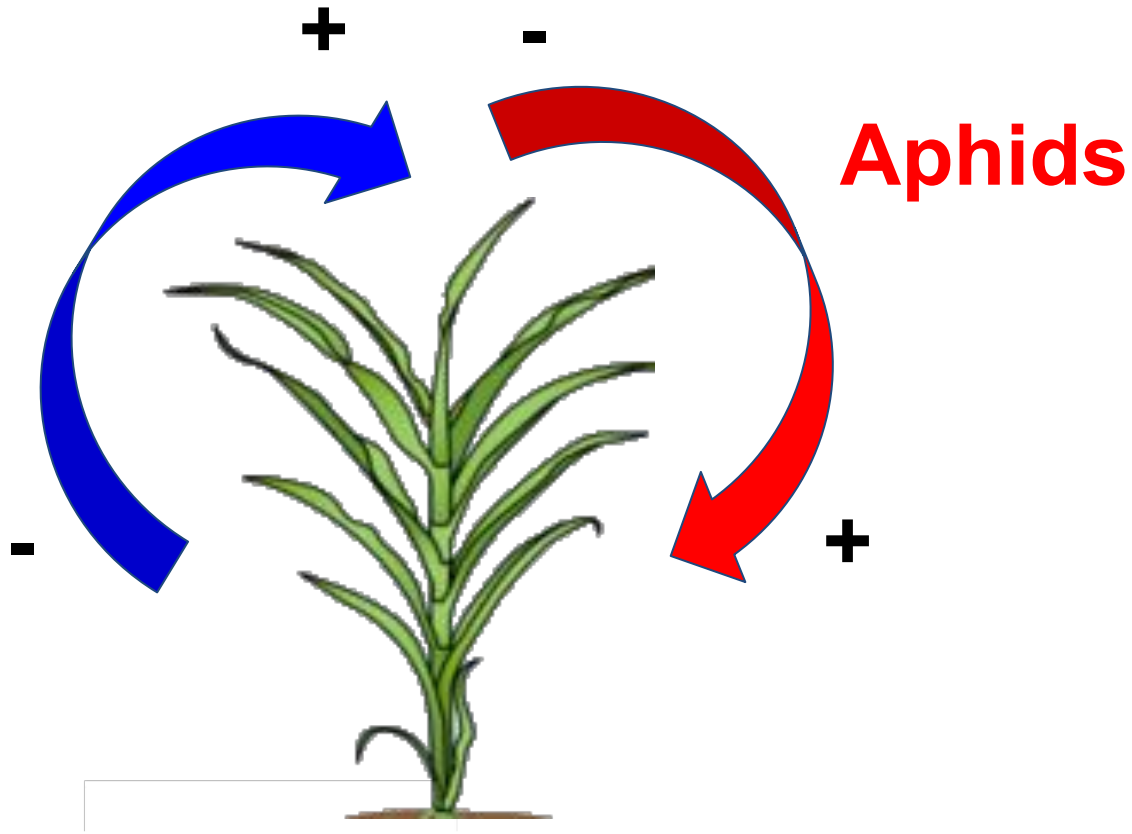
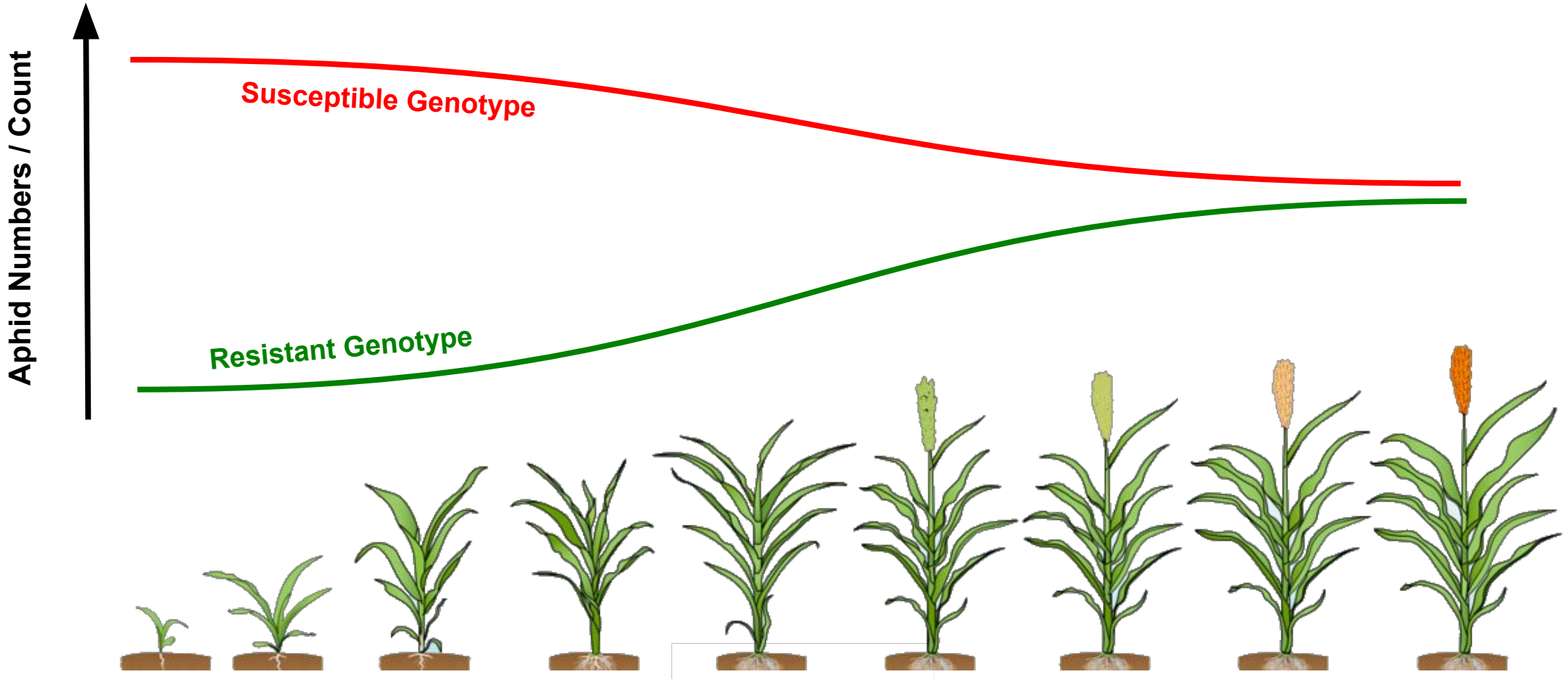
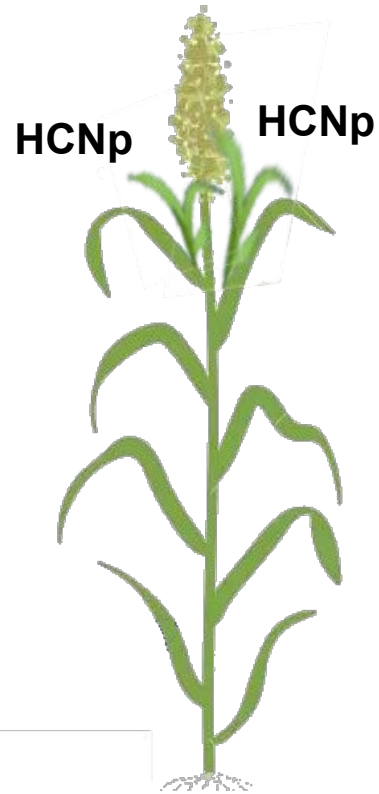
Hypothesis (& prediction)



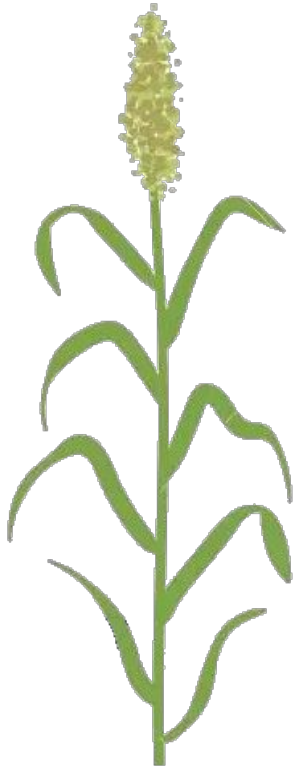

Aphid Numbers / Count
Susceptible Genotype
Resistant Genotype

Young upper lateral branches seem to increase resistance levels

More Resistant



Less Resistant



- The major cyanide detoxification gene CAS (Machingura *et al.* 2016) is among a handful of candidate causative genes identified in the selected region at the *RMES1* locus.
- Dhurrin has been identified as a major greenbug feeding deterrent (Dreyer *et al.* 1981).
- Zerazera genotypes, related to UniQ founder lines, tend to have high HCN-p levels and they also maintain high levels until panicle exsertion and pre-anthesis stage (McBee and Miller 1980).
- Extremely SCA susceptible genotypes such as TX7000 are known to have extremely low HCN-p levels (McBee and Miller 1980).
- The new SCA-resistant Chibas sorghum varieties are avoided by livestock at an early stage of their development compared to older sorghum varieties and maize.
- The Chibas sorghum varieties appear more resistant to fall armyworm (FAW; Spodoptera frugiperda) (another serious pest undergoing a global outbreak) compared to maize.

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Developing a high-throughput assay to quantify HCN

Kristen Johnson

Jean Rigaud Charles, Carl Carl VanGessel, Brian Rice,

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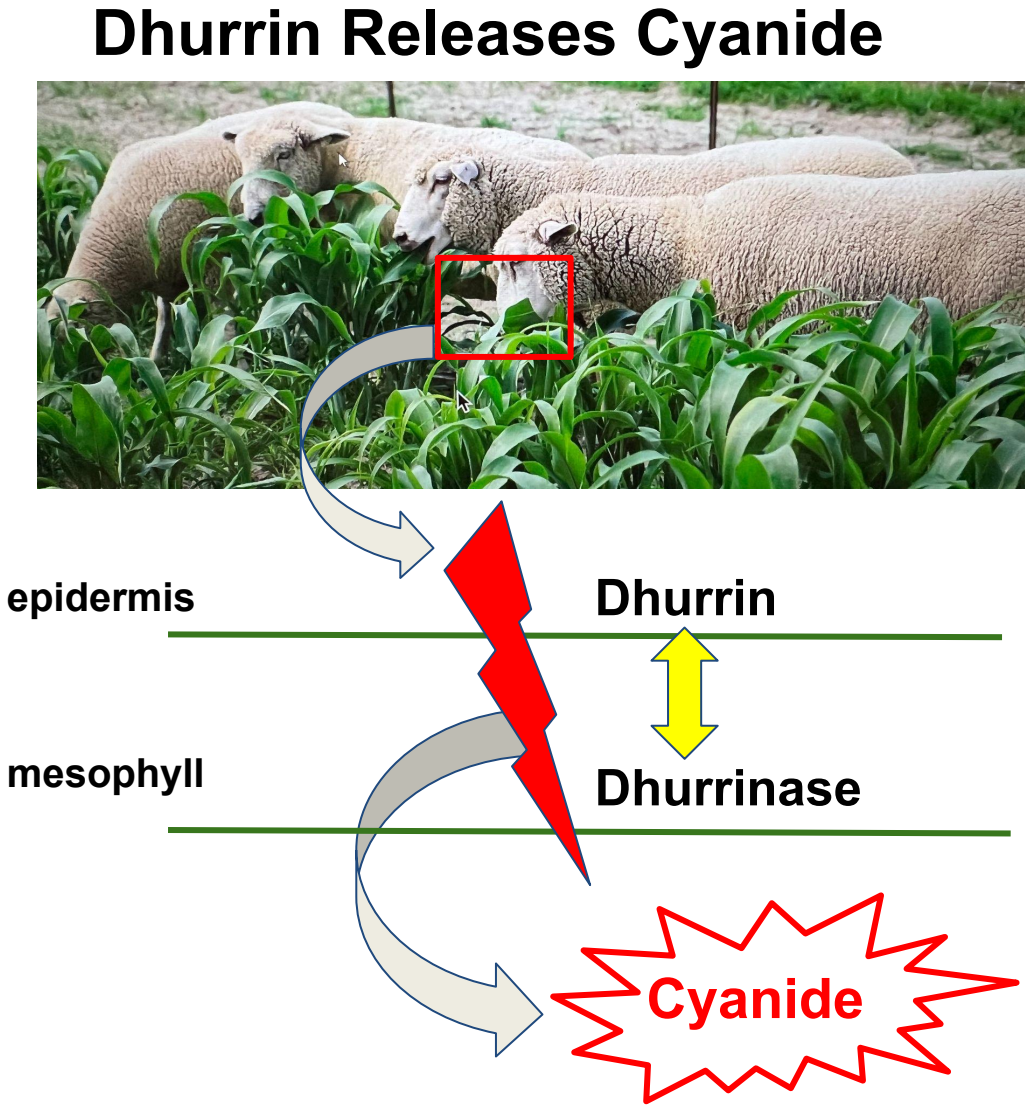
Developing a high-throughput assay to quantify HCN

Research Goal: To understand the role cyanogenic potential (HCNp) has in stress responses such as tissue damage, SA infestation, drought etc.

Sorghum Breeding Requires Accurate HCNp Detection

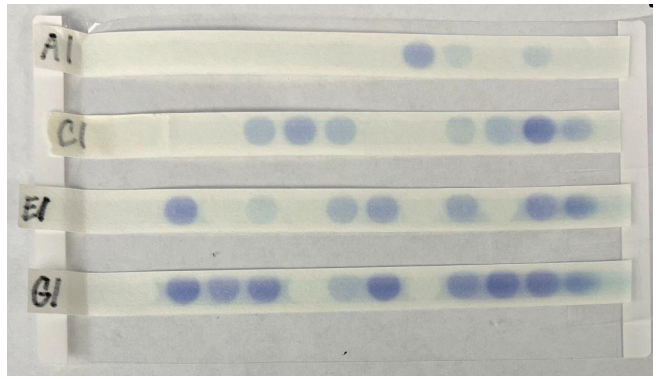
Roadblock: There is no fast, affordable, semi-quantitative, high-throughput phenotyping method to detect HCNp



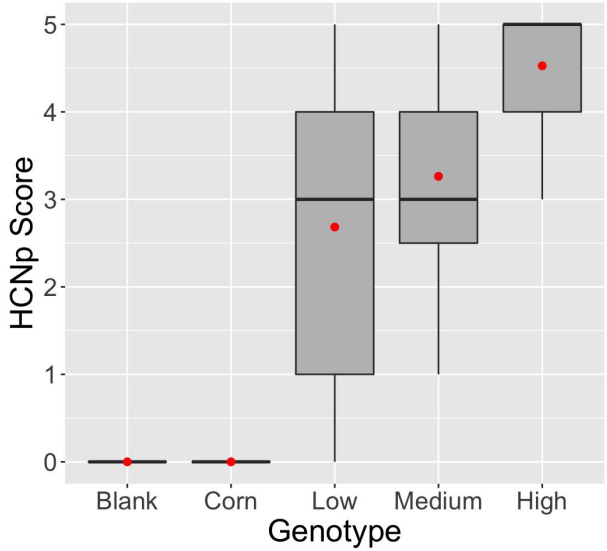
A method to phenotype cyanogenic potential

1. **Affordable**
   - Estimate per sample~$0.12
2. **Accessible**
   - All supplies found online or in a lab
3. **High-throughput**
   - Practical in a field setting
   - 48 samples/plate
   - Visual Scoring

HCNp phenotypic measurement



Confirming Assay Reliability



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Better Varieties

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Breeding for Photoperiodic SA resistant sorghum (Population B)

Gael Pressoir

Jean Rigaud Charles, Carl Carl VanGessel, Brian Rice,
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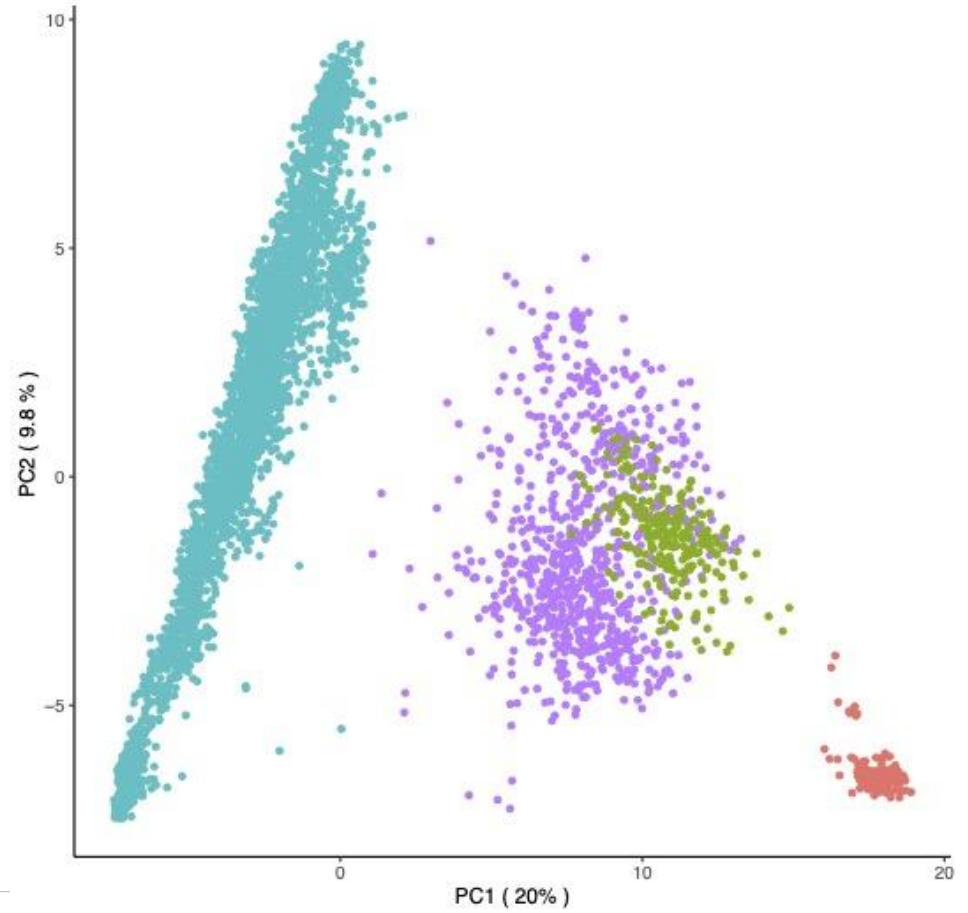
Like in the early days of our main population

Out of over 20,000 S1/F2 genotypes from over 40 crosses between population A (Chibas main population fixed for RMES1) and some local photoperiodic varieties (susceptible to SA) we have selected under 100 individuals (resistant, filled panicle).

The other two populations did not give strongly resistant genotypes (in spite of segregating for RMES1)



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Genetic gain for aphid resistance, drought resistance and yield stability, in Chibas main population

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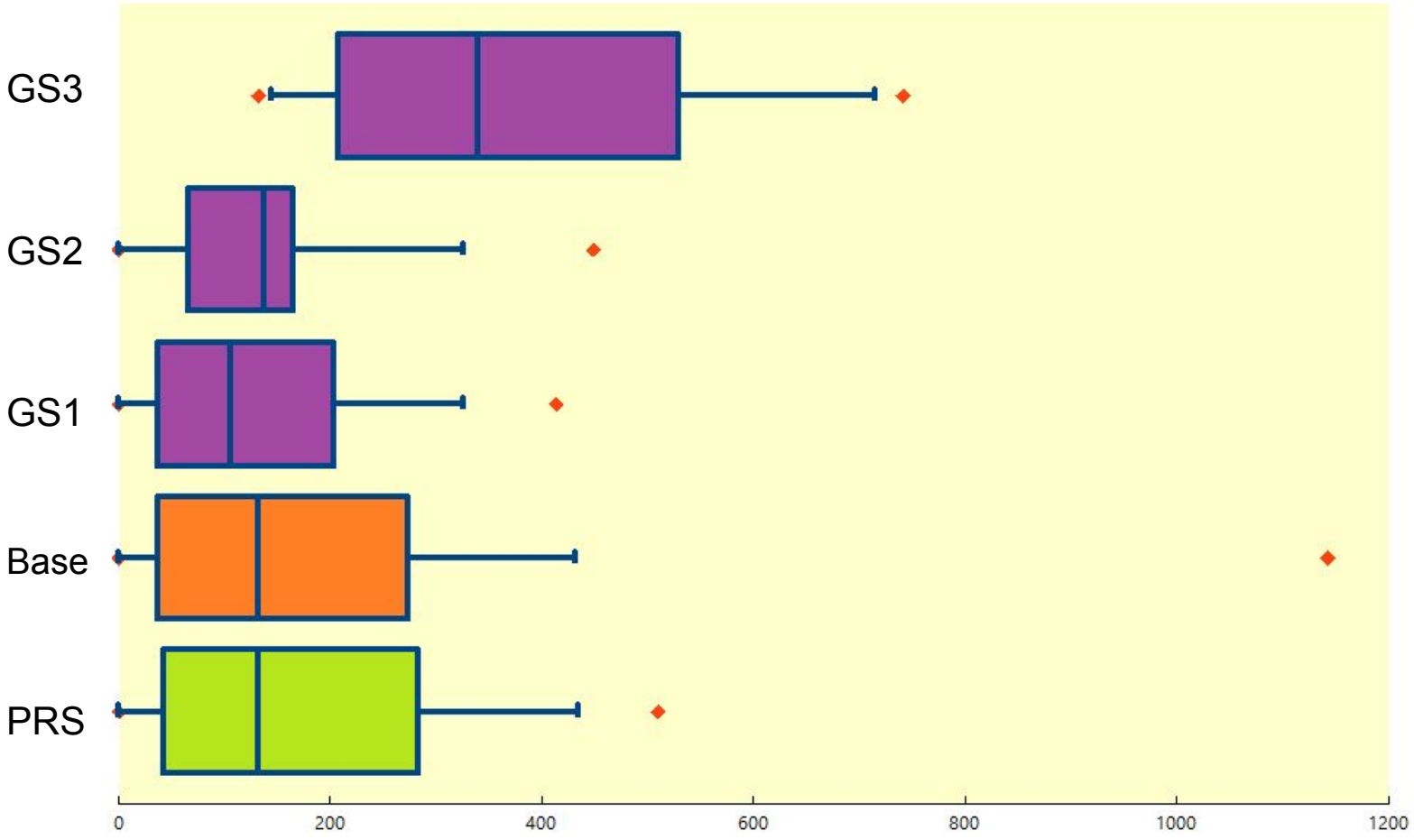
With SMIL part 1 we demonstrated that Genomic Selection works (see last year report)

- We are seeing an increase level of performance of the newest inbreds (coming out of our genomic selection program) even with strong aphid infestations
- Resistance to SA has been increasing over time in the main population (prediction - hypothesis: yield stability is driven in part by SA Resistance)

Results on grain yield

Grain yield in Kg/ha water stress, and "humongous" aphid (SA) infestation

Testing new lines



- Now we are moving to integrate Genomic Selection, Physiological selection and multi-local phenotypic selection to maximise genetic gain (USAID-ILCI) - my thesis

- The work on Dhurrin and SA resistance will be a major part of this

Predictions

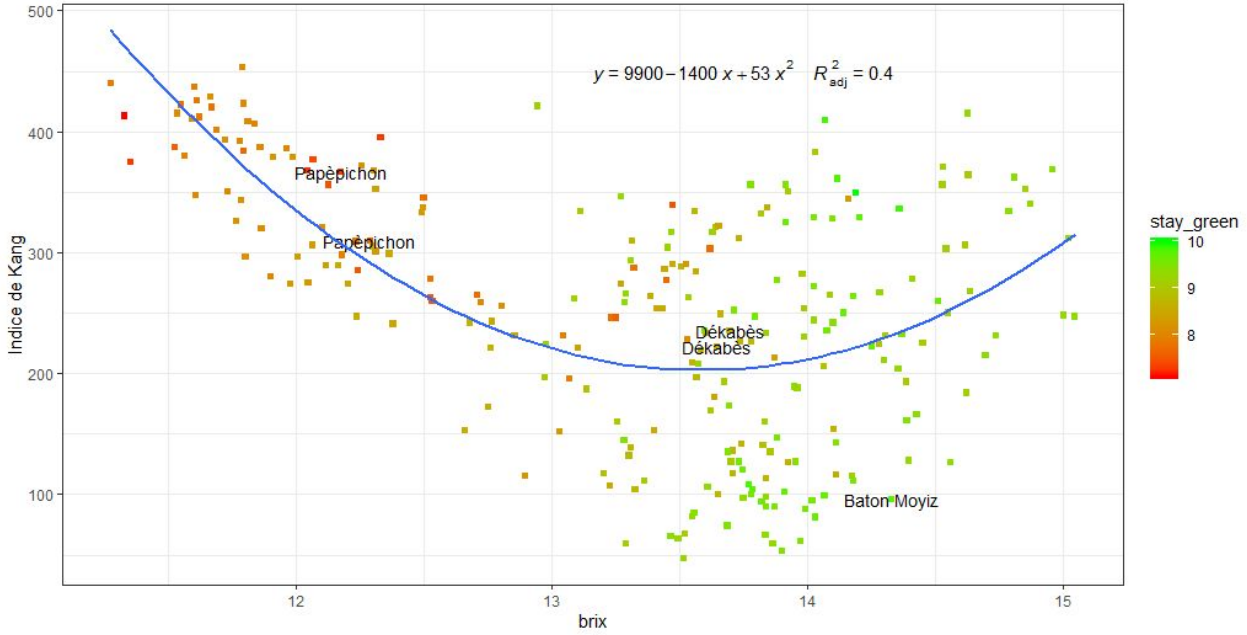
- HCNp is a predictor of resistance and also a predictor of agronomic performance under strong aphid pressure
- We can predict resistance by predicting HCNp (genomic prediction)
- Dhurrin levels, and HCNp, in young leaves increase the resistance to SA but also contribute to staygreen and drought resistance - major contributor of yield stability

(hypothesis being tested, encouraging initial results)

Traits contributing to yield stability

- Increased HCNp in the young leaves
  ⇒ increased staygreen
- Increased HCNp in young leaves
  ⇒ increased yield stability
- Increased HCNp in young leaves
  ⇒ increased resistance to SA

Are there other mechanisms for increasing resistance?



Last year we described the genetic correlation between Staygreen and stem sugars and yield stability. This year we will add Dhurrin (HCNp) to the mix

On track to reach our goals and objectives

- OBJECTIVE 1: Better understand the genetics of resilience traits and effects on varietal development:
  RMES1 validated novel populations; other QTLs are present

- OBJECTIVE 2: Better understand the physiology of resilience traits and effects on varietal development:
  We have an inexpensive assy to test our hypothesis (HCNp)

- OBJECTIVE 3: Marker technology and breeding strategies for resilience traits

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Feed the Future Innovation Lab for Crop Improvement

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These studies were made possible by the support of the American People provided to the Feed the Future Innovation Lab for Collaborative Research on Sorghum and Millet (SMIL) and the Innovation Lab for Crop Improvement (ILCI) through the United States Agency for International Development (USAID). The contents are the sole responsibility of the authors and do not necessarily reflect the views of USAID or the United States Government.

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AND ALSO TO OUR OTHER DONORS

PLANT BREEDING TAKES LONG, ITS A PROGRAM… NEVER A PROJECT

Photoperiodic sorghum with SCA resistance

Development and release of *Papèpichon*, the first Haitian SCA resistant variety, with support of Akosaa and funding from Canada Global Affairs

Establishment of our sorghum breeding program and our rapid cycling strategy with support from CIRAD and funding from the French Agence Nationale de la Recherche (appel Flash Haiti)

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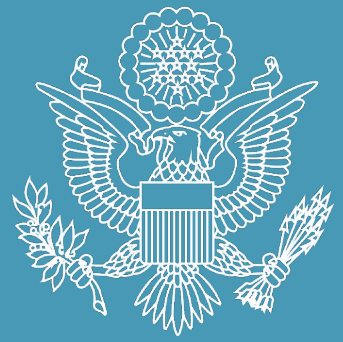

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