



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative



Collaborative Research
on Sorghum and Millet

SAWAGEN: Improving Sorghum Adaptation in West Africa with a Genomics-Enabled Breeding Network

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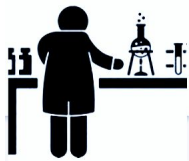
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FROM THE AMERICAN PEOPLE

March 24, 2022

SMIL ANNUAL REVIEW MEETING

KANSAS STATE
UNIVERSITY

An effective and durable R&D network for WA NARS



Researchers

Deliver knowledge that facilitates the breeding programs

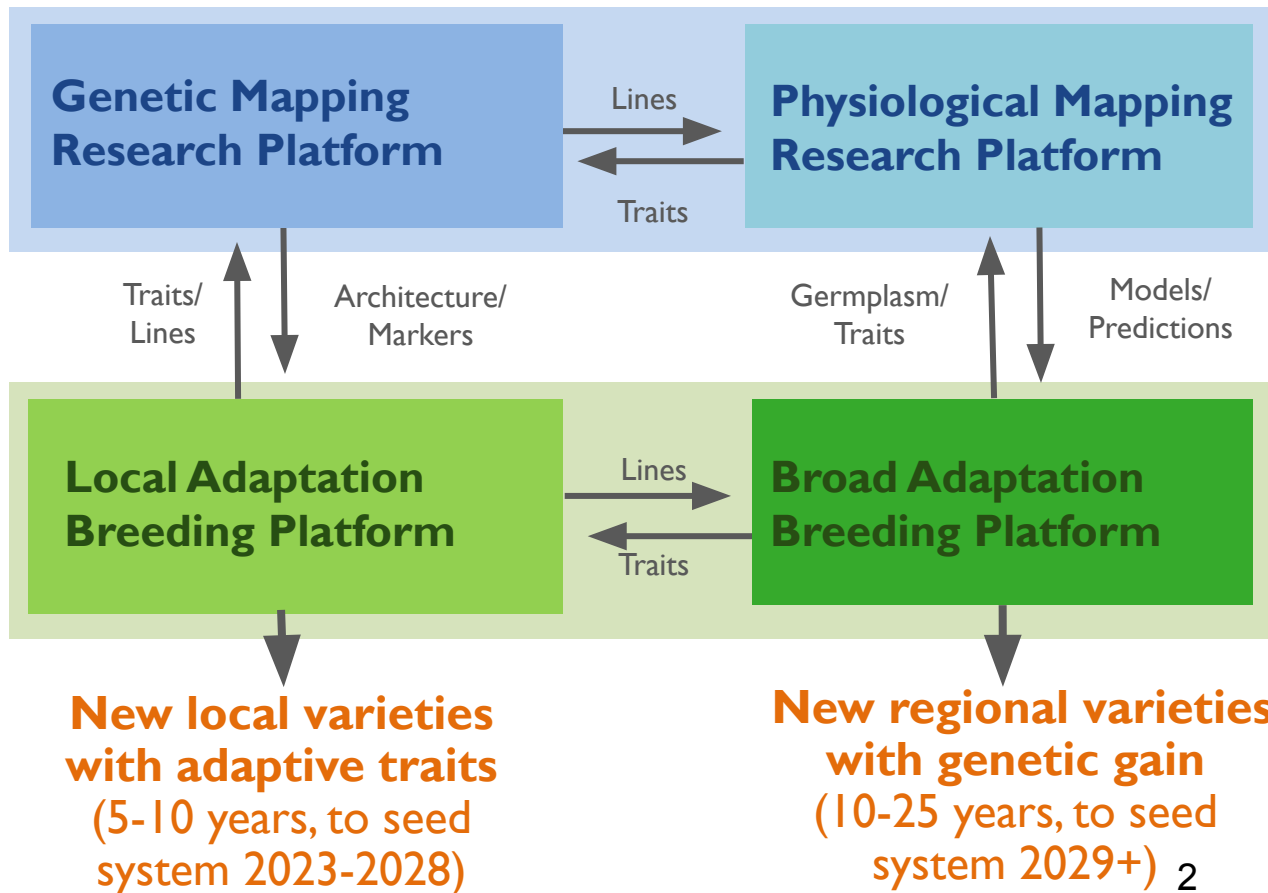


Breeders

Deliver varieties that meet defined product profiles



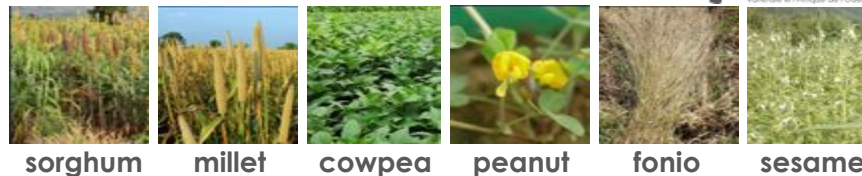
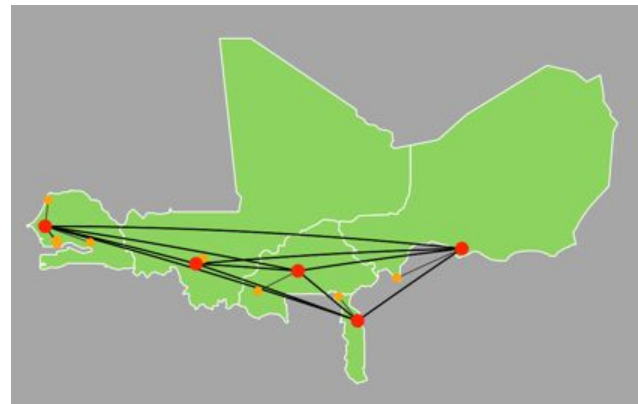
Farmers and end-users



SAWAGEN has strong links with the IAVAO crop network



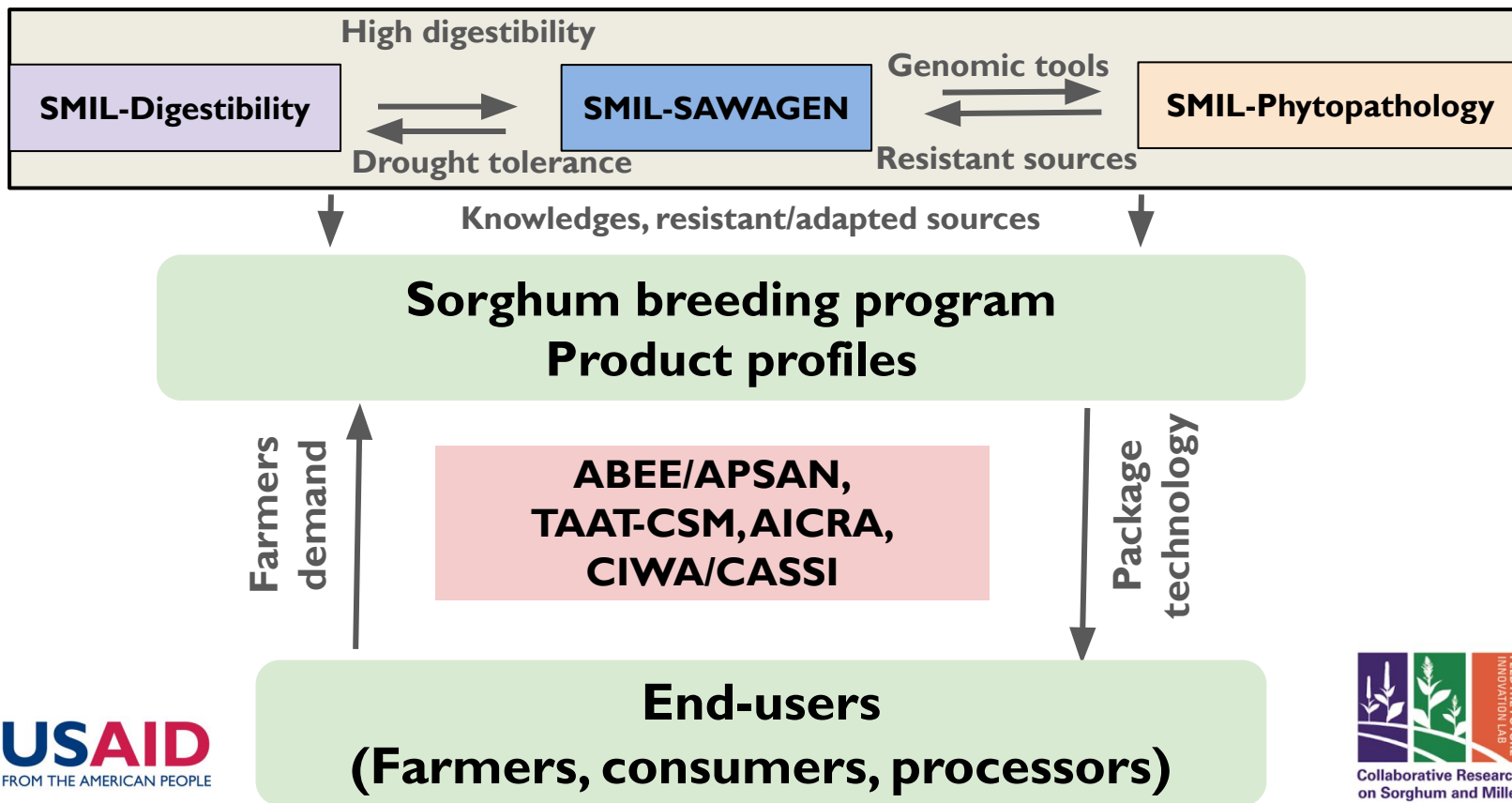
5 countries: Burkina Faso, Mali, Niger, Sénégal, Togo



- Common germplasm collectively nominated and evaluated each year in the network
- Traits standardisation across countries and partners (ontology)
- A common database (BMS)
- A common governance (charter)



Project link with on-going FtF or non FtF initiatives



Local adaptation breeding platform (LABP)

Platform lead: Jacques Faye (ISRA-CERAAS)

Cyril Diatta (ISRA, Senegal)

Nofou Ouedraogo (INERA, Burkina)

Jack Eyanawa Akata (ITRA, Togo)

Ardaly Ousseini, Fanna Maina (INRAN, Niger)

Terry Felderhoff (KSU)



Local adaptation breeding platform (LABP)

Objective: Deliver improved versions of locally-preferred varieties carrying winning traits (Striga resistance and stay-green) in the 5 to 10 years horizon

- **ARR 1.1, 1.2, 1.4 : Nganda, Sorvato-1, and Mota Maradi** carrying *lgs* / Striga resistance allele for Senegal, Togo, and Niger
- **ARR 1.3 and 1.5: Kapelga and Faourou** carrying *Stg1-4* stay-green drought tolerance alleles for Burkina Faso and Senegal

Nganda with *lgs1* striga resistance for Senegal

- Cross between **Nganda** and **SRN39** (Striga resistance donor)
- Currently we're at **BC2F1** generation
 - Hot off-season (HS) 2022 (**BC2F2**)
 - Rainy season (RS) 2022 (**BC2F3**)
 - **pot evaluation** (cool off-season, CS 2022)
- Striga "hot spot" fields identified; **seed multiplication in HS 2023**
- Rainy season 2023: on **farm evaluation** and participatory variety selection (**PVS**)
- Rainy season 2026: **delivered to the seed system**



SAWAGEN nurseries in Senegal

Sorvato-I with *lgs1* striga resistance for Togo



Jack Akata

- Cross made between Sorvato-I and SRN39
- Currently at BC2F4 generation
 - make BC2F5 (Hot off-season 2022)
 - using **BC2F5** start field evaluation (Rainy season 2022)
- **Seed multiplication** in RS 2022 and CS 2022
 - Provide **seeds to seed producers** for RS 2023



BC2F4 lines at Davié station, Togo

Mota Maradi with *lgs* striga resistance for Niger

- Cross between Mota Maradi and SRN39
- Currently at BC4F1/BC4F1 generation
→ BC5F1/BC4F1 (Hot off-season 2022)
→ Field evaluation of BC4F3 in Striga hot spots and PVS (Rainy season 2022)
- **Seed multiplication** in RS 2022
→ **to seed system** (RS 2023)



Striga hot spots



Konni station, Niger

Mota Maradi, Sepon82, MR732 with *lgsI* Striga resistance for Niger

Country	Variety	Donor	Trait to be added	Generation
KSU/Niger	Mota Maradi	SRN39	Striga resistance	BC3F3/BC1F3
KSU/Niger	MR732	SRN39	Striga resistance	BC5F1/BC3F3
KSU/Niger	Sepon 82	SRN39	Striga resistance	BC2F1



- Lines carrying the *lgsI* allele were identified
- Striga germination assay is on-going at Penn-State University
- Field evaluation in hot spot in 5 locations in Niger (rainy season 2022)

Kapelga with stay-green drought tolerance for Burkina Faso

- Cross between **Kapelga** and **B35 (BTx642)**
 - Currently at BC2F1/BC1F2 generation → Dry off-season 2022: **BC2F2** and **BC1F3** lines
 - Rainy season 2022: start **field evaluation**
- **Registration process in 2023**
- **Registration to National catalog → producers in 2023**
- **Seed multiplication → to seed system (RS 2024)**



Kamboinse research station

Faourou with stay-green drought tolerance for Senegal

- Cross between **Faourou** and B35/BTx642 line
 - Currently at BC3F2 generation → **BC3F3** lines (Hot off-season 2022)
- Rainy season 2022: **field evaluation on station** of the **BC3F3** lines;
- Cool off-season 2022: **Lysimeter experiment** to evaluate effects of stay-green alleles
- Rainy season 2023: on **farm evaluation**, **PVS** and **field day** on station
- Rainy season 2025: deliver **to the seed system**



Expected progress for the deliverables in 2022

- Effectively establish marker-assisted backcross selection in the 4 breeding programs
- Start field evaluation of lines carrying *lgs*/ striga resistance and stay-green alleles and/or pod evaluation for striga resistance
- Verify if the *Stg* alleles predict stay-green phenotype in breeding populations under lysimeter and drought stress experiments
- **Challenges:**
 - Lack of *Striga* infested field in research station: limits field evaluation
 - Difficulties to evaluate lines in hot spots (long distance, field variation)



Broad adaptation breeding platform (BABP)

Platform lead: Cyril Diatta (ISRA)

Aissata Mamadou & Ardaly Ousseini (INRAN, Niger)

Nofou Ouedraogo (INERA, Burkina)

Jack Eyanawa Akata (ITRA, Togo)



Objective of BABP

- Develop **broadly-adapted germplasm** as a foundation for long-term varietal delivery

ARR 4.1: Development of a West Africa Backcross Nested Association Mapping (BCNAM) resource

ARR 4.2: Multi-environmental evaluation and participatory varietal selection of promising Mini-NAM lines in West Africa agro-ecological zones

ARR 4.3: Adoption of Breeding Management System (BMS) for data management and sharing in West Africa NARS



Development of Backcross Nested Association Mapping (BCNAM)

Goal: Broadly-adapted germplasm (elite and diverse) for long-term genetic gain

- **Four recurrent parents:**
 - **Nganda** (Senegal)
 - **Sepon82** (Niger)
 - **Sorvato I** (Togo)
 - **Sariaso II** (Burkina)
- **Sixteen donor** parents selected based on production constraints and farmer's preferred traits

Recurrent Parent	Donor Parents	Traits	Pays	F1	BC1F1	BC1F2	BC1F3	BC1F4	BC1F5
Sariaso11	Kapelga	Grain quality (Tô)	Burkina	F1	BC1F1				
	E36-1	Stay green	Burkina	F1	BC1F1	BC1F2			
	B35	Stay green	Burkina	F1	BC1F1	BC1F2			
	CCAL 1/13-1-1-1	Cecidomyia	Burkina	F1					
Sépon82	CE1516262 (IRAT 204)	Anthracnose	Niger	F1					
	Mota Maradi	Long Smut	Niger	F1					
	MDK	Grain quality, Stray green	Niger	F1					
	ICSV88032	Cecidomyia	Niger	F1					
Nganda	F2-20	Grain mold and Striga	Senegal	F1					
	N13	Striga	Senegal	F1	BC1F1	BC1F2			
	Sureño	Grain mold and foliar diseases	Senegal	F1	BC1F1	BC1F2			
	L28	Big grain	Senegal	F1	BC1F1	BC1F2			
	Grinkan	Seedling vigor & open panicle	Senegal	F1	BC1F1	BC1F2			
	SK5912 (Short Kaura)	Long panicle	Senegal	F1	BC1F1	BC1F2			
Sorvato1	SRN39	Striga	Togo	F1	BC1F1	BC1F2	BC1F3	BC1F4	
	RTx7000	Drought	Togo	F1	BC1F1	BC1F2	BC1F3		
	Ni49 (WASAP)	Big grain	Togo	F1	BC1F1				



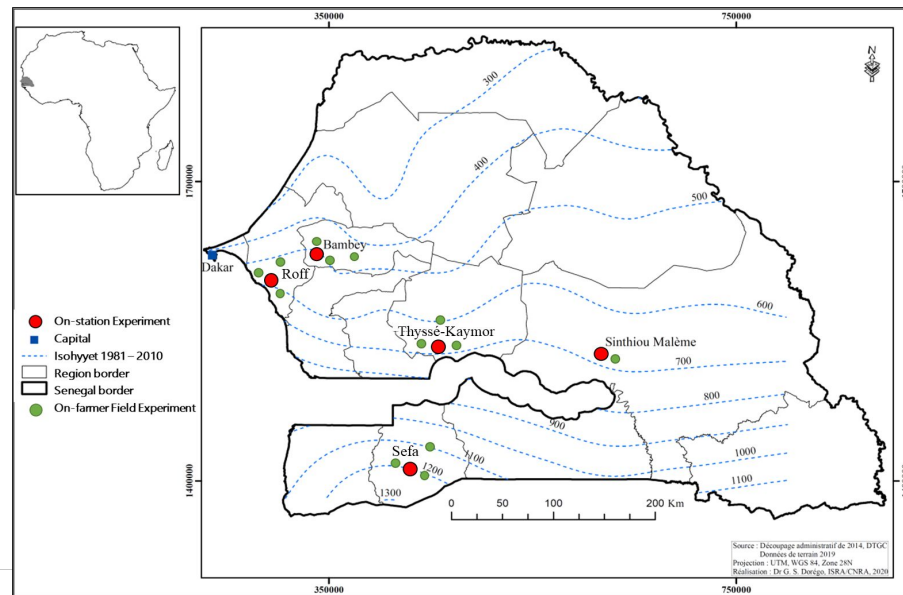
Multi-environment & participatory selection of Mini-NAM lines

On-station Evaluation

25 promising lines from SMIL Phase-I evaluated at Bambey, Roff, Sinthiou, Sefa (**red dots**) during the 2019, 2020, 2021 rainy seasons

On-farm Evaluation

The 7 lines combining higher yield and resistant to grain mold were evaluated in 13 farmers' fields (**green dots**) during the rainy season 2021



Multi-environment selection of Mini-NAM lines

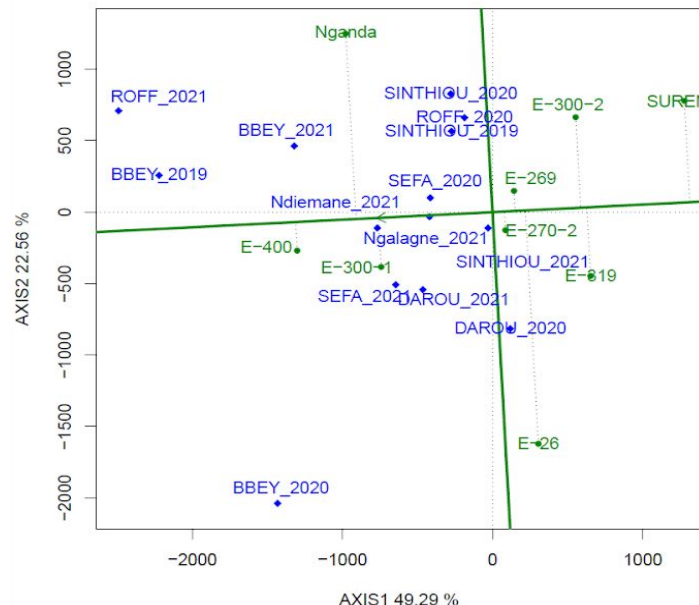
Performance and stability

Line **E400** is the best performing followed by **E300-1**; E270-1; E269

Line **E269** is the most stable followed by **E270-2**; E400; E300-1

Average grain yield : 1,5 - 2t/ha

Average grain mold Score : 2



Participatory variety selection of Mini-NAM lines in Senegal

Participatory variety selection (PVS)

PVS at Roff, Séfa, and Sinthiou
Maleme in 2021 growing season

Total of 45 farmers
(26 women; 19 men)



Multi-environment & participatory selection of Mini-NAM lines

Best farmers' preferred lines:

- **E319**
- **E269**
- **E300-2**
- **E300-1**
- **E400**

LINE	SINTHIU	SEFA	ROFF	RANK
<i>E-319</i>	1.5	1.2	1.5	<i>1</i>
<i>E-269</i>	1.4	1.1	1.8	<i>2</i>
Nganda	2.0	1.5	1.0	3
<i>E-300-2</i>	2.1	1.1	1.8	<i>4</i>
<i>E-300-1</i>	2.0	1.5	2.0	<i>5</i>
<i>E-400</i>	2.5	1.6	2.7	<i>6</i>
E-26	2.0	2.7	2.2	7
E-270-2	2.5	2.8	1.7	8
Sureño	1.6	2.2	2.5	9



Participatory selection of Mini-NAM lines

Farmers' preferred traits

Men:

Mostly prioritize agronomic traits

Women:

Prioritize both grain quality and agronomic traits

FARMERS' PREFERRED TRAITS	RANKING AT SEFA		RANKING AT ROFF		RANKING AT SINTHIOU	
	MAN	WOMAN	MAN	WOMAN	MAN	WOMAN
Grain yield	1	-	1	-	1	1
Big grain	2	1	5	3	-	-
Big and open panicle	3	-	7	4	-	5
Short maturity cycle	6	4	2	5	2	7
Medium plant height	7	-	4	-	-	2
Biomass yield	-	-	7	-	4	6
White grain	4	3	6	1	-	3
Grain quality (suitability for local dishes)	5	2	-	2	3	4
Grain mold resistance	-	5	3	7	-	9
Plant Vigor	-	6	-	-	-	8



Multi-environment & participatory selection of Mini-NAM lines

- Based on agronomic performance and PVS (farmer's preferences) **05 lines** have been selected

Next steps:

- Seed multiplication of the 5 lines
- Tests for suitability for local food
- Start registration for 3 best lines in 2022
- New varieties to **seed system in 2023**

LINES	GRAIN YIELD	GRAIN MOLD SCORE	FARMERS' RANKS
E-400	2176	2	6
E-300-1	1917	2	5
E-269	1577	2	2
E-300-2	1683	2	4
E-319	1534	2	1
Nganda	2052	3	3
SURENO	1170	2	9



Adoption of BMS for data management and sharing in West Africa NARS

- All NARS Breeders have been trained on BMS
- All 2021 field-books were prepared using BMS
- Historical data are being migrated on the BMS
- Data are being collected with electronic devices
- Barcode reader and field label printers purchased (Senegal)

Next steps

- Implement barcodes field labelling
- Training on seed storage management



Field label Printer ZEBRA ZT230



Barcode field Label

Genetic Mapping Research Platform (GMRP)

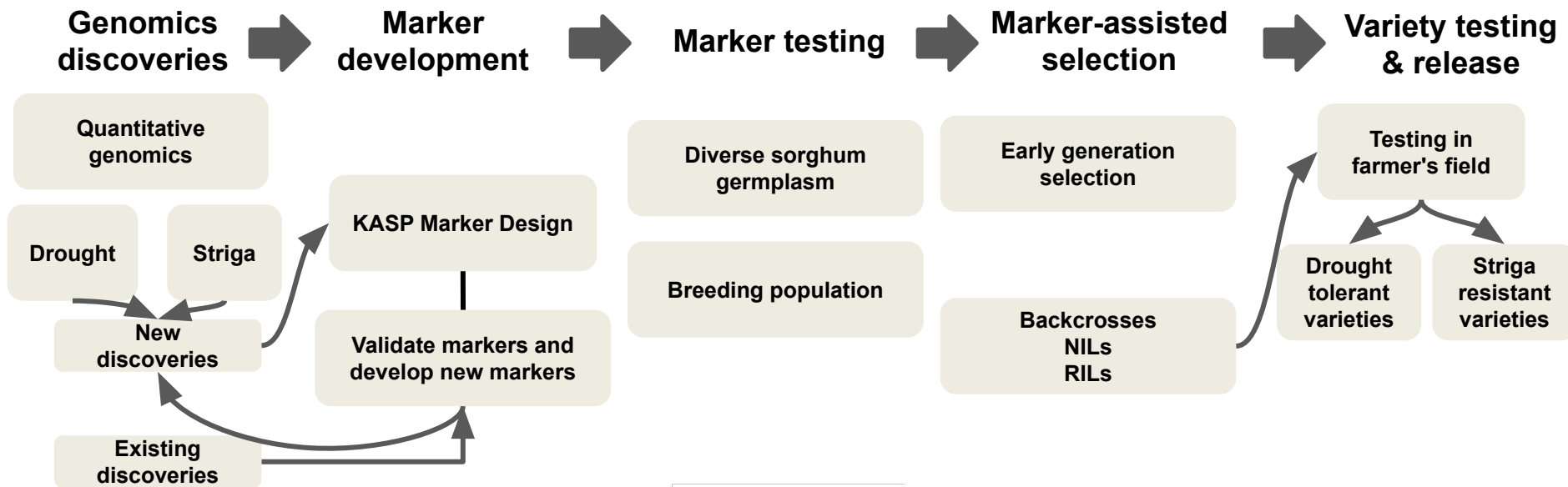
Platform lead: Fanna Maina (INRAN)
Jacques Faye & Bassirou Sine (ISRA-CERAAS)
Terry Felderhoff (KSU)



Objectives of GMRP

- **Objective:** Deliver genetic knowledge and tools to breeders that solve their roadblocks/gaps
 - Generate genetics knowledge that guides breeding strategy
 - Develop genetic tools to facilitate breeding (trait-predictive and background markers).
- **Anticipated Research Results:**
 - ARR 2.1: KASP markers for *Striga* resistance alleles at the *lgs1* gene
 - ARR 2.2: Genetic maps, KASP markers, and isogenic lines for novel drought resilience traits

Workflow: Genomics discoveries to varietal release



Progress made in 2021

- KASP markers developed and validated *Striga* resistance and drought tolerance
→ delivered to LABP
- *Striga* resistance evaluation via germination assay to evaluate and validate lines with favorable/unfavorable alleles at *lgs1*
- Quantitative Trait Locus mapping for drought stress in WASAP
(Faye et al. 2021, Maina et al., *submitted*)
- Marker development and testing for novel drought tolerance QTLs

Striga resistance evaluation via germination assay

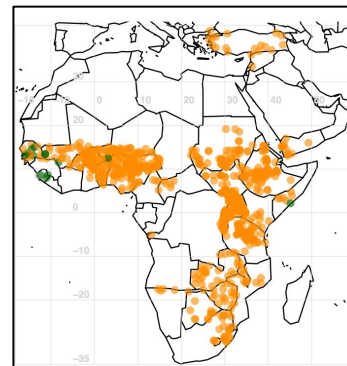
- **Hypothesis:** Favorable allele at *lgs1* confers *Striga* resistance by reduced germination stimulant
- *Striga* germination assay in pots for known varieties during rainy season in Niger
- Genotypes tested include SRN39 donor parent variety from breeding programs
- Validation of backcross populations ongoing for *Striga* germination assay at Penn State (Lasky lab)



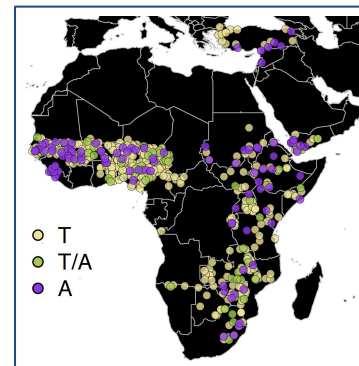
Pot assays: *Striga* emergence

Evidence of drought adaptation in WASAP

- **Goal:** Discover & deliver drought tolerance markers for West African breeding programs
- Marker traits associations (MTA) with drought response in WASAP
- MTAs colocalized with stay-green genes (Faye et al., 2021, Maina et al., *submitted*)
- Novel loci underlying drought response (Maina et al., *submitted*)



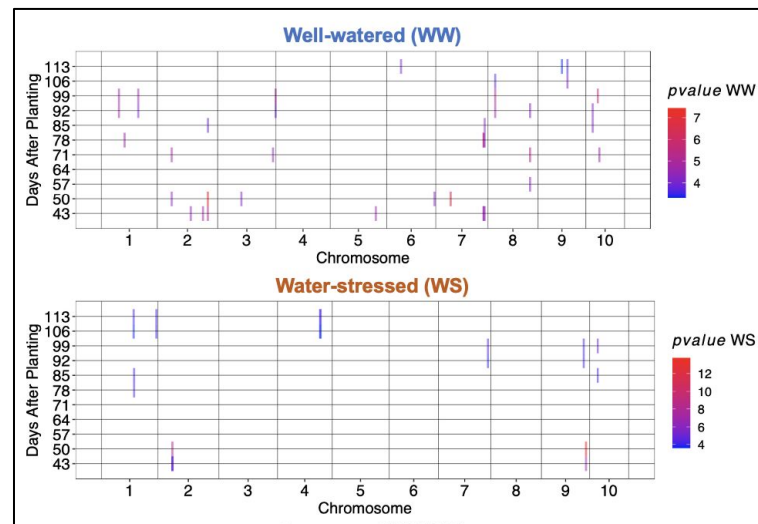
Allelic distribution for
S3_66738018



Allelic distribution for
S7_50055849

MTAs for water-use dynamic for drought tolerance

- **Goal:** Discover & deliver predictive markers underlying water use under drought stress
- Water use measured over 12 weekly time points
- Significant genetic variation in water use ($p < 10^{-5}$)
- Several MTAs appear at 2-3 consecutive timepoints
- MTAs could be used as trait-predictive markers used in breeding for climate-resilience



GWAS for water use and its drought response

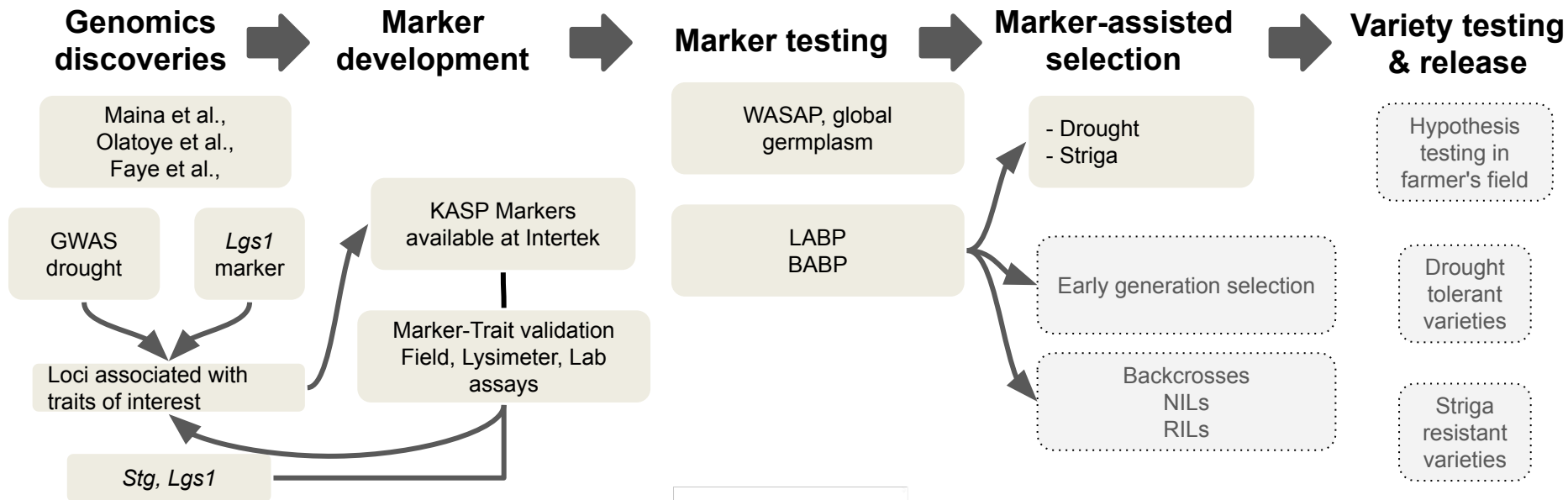
Testing our novel drought tolerance markers

- Novel markers underlying drought response in WASAP are being tested (11 KASAP markers for validation).
- Evaluation of WASAP drought tolerant varieties under managed environment (Lysimeter at Bambey)
 - Putative drought tolerant accessions
 - Donor accessions of putative MTAs
- Progeny of B35*Nganda (BC3F3) carrying favorable alleles will be evaluated in the lysimeter



**WASAP drought validation in lysimeter
(Bambey, Senegal)**

Workflow: Genomics discoveries to varietal release



An effective and durable R&D network for WA NARS



Researchers

Deliver knowledge that facilitates the breeding programs

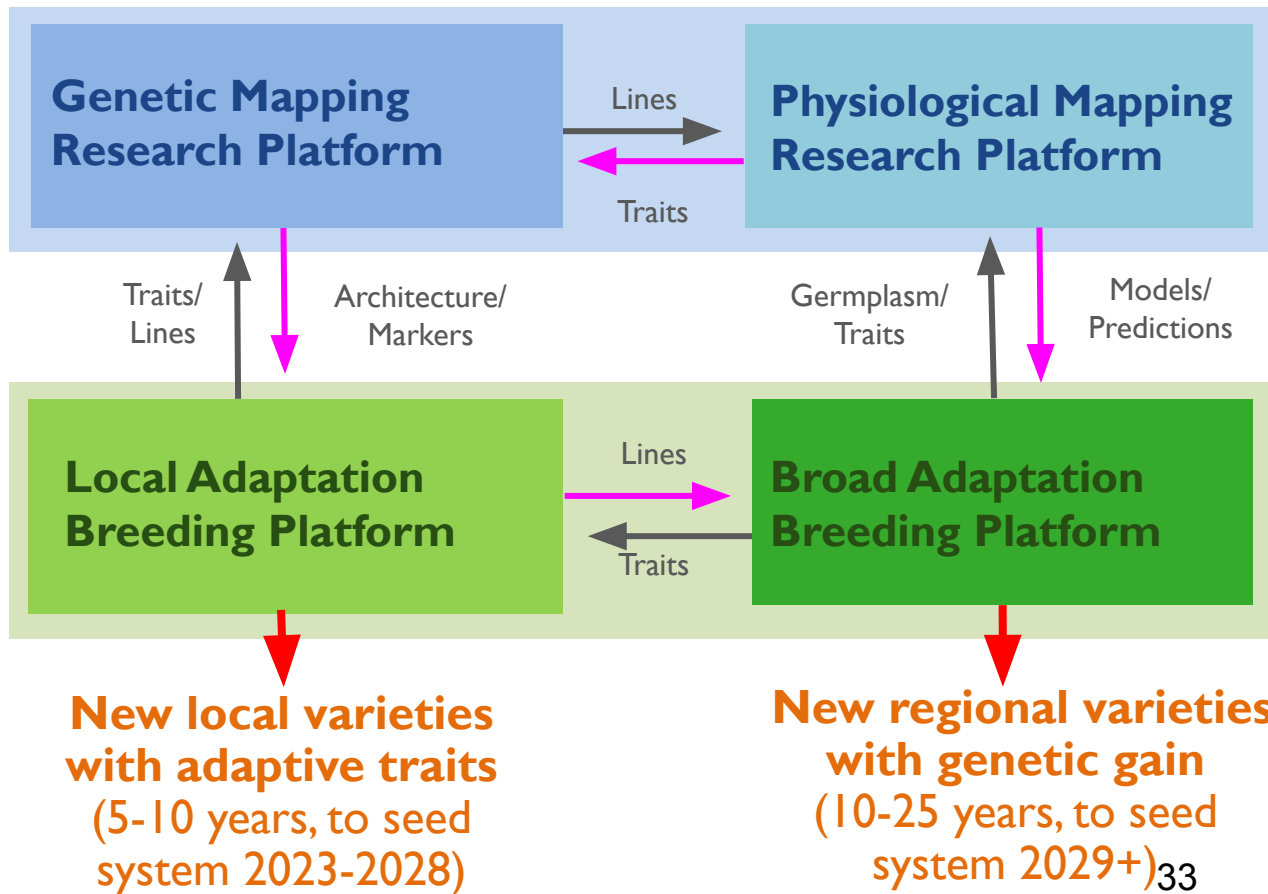


Breeders

Deliver varieties that meet defined product profiles



Farmers and end-users



Questions and comments?

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Striga resistance allele for Senegal

- **Crosses made between elite and SRN39 line**
- Marker-assisted backcross selection at early generations

Country	Preferred variety	Donor	Winning trait	Generation 2022
Senegal	Nganda	SRN39	Striga resistance	BC2F3

Genotype	Striga (snpSB00487)
SRN39_1	A:A
SRN39_1	A:A
Nganda_1	G:G
Nganda_1	G:G
F1(Nganda x SRN39)/1-1	A:G
F1(Nganda x SRN39)/1-2	A:G
F1(Nganda x SRN39)/1-3	G:G
F1(Nganda x SRN39)/1-4	G:G

Stay-green drought tolerance smallholder farmers

- **Cross between elites and B35/BT_x642 line**
 - Marker-assisted selection at early generations
 - Rainy season 2022: **Field evaluation** of the **BC3F3** lines

MAS has been successfully applied to efficiently select genotypes carrying the Stay-green alleles from B35

Genotype	Stg3a (snpSB00460	Stg3b (snpSB00098	Stg3b (snpSB00468)
Faourou_1	A:A	C:C	G:G
Faourou_1	A:A	C:C	G:G
B35_1	C:C	G:G	A:A
B35_1	C:C	G:G	A:A
BC2F1(Faourou x B35)/2-1	A:A	C:C	G:G
BC2F1(Faourou x B35)/2-1	A:A	C:C	G:G
BC2F1(Faourou x B35)/2-2	C:A	G:C	G:A
BC2F1(Faourou x B35)/2-2	C:A	G:C	G:A
BC2F1(Faourou x B35)/2-3	C:C	G:C	G:A
BC2F1(Faourou x B35)/2-3	C:C	G:C	G:A
BC2F1(Faourou x B35)/2-4	C:A	C:C	G:G
BC2F1(Faourou x B35)/2-4	C:A	C:C	G:G

Country	Preferred variety	Donor	Winning trait	Generation
Senegal	Faourou	B35	Stay-green	BC3F3