CGIAR

Bioversity International and the International Center for Tropical Agriculture (CIAT) are CGIAR Research Centers.
CGIAR is a global research partnership for a food-secure future.

Alliance
Bioversity & CIAT

Establishing sustainable solutions to cassava diseases in mainland Southeast Asia

-- Objective 2 Breeding and Selection

Xiaofei Zhang, Cu Thi Le Thuy, Phuong Duc Pham, Trang Do Thi, Jonathan Newby

2023 0ct 01

Managed Separated Populations for Four Products

BC, Beta-carotene; CQ, cooking quality; WX, waxy starch; SG, small granule starch; PQ, processing quality

1) Cassava for **starch** and animal feed
2) **Biofortified** cassava for human consumption
3) Fresh and dried roots for **human consumption**
4) Cassava for **specialty** starch
5) Processing- **granulated** and paste for human consumption

TPE: subhumid and semi-arid lowland tropics

40 ha of breeding trials at 3 locations

Future Seeds – Genebank

Provide both trait donors and improved breeding populations to **IITA and NARES**.

CIAT

Product Evaluation & Release-variety

Agrosavia
Embrapa

IITA

Product Evaluation & Release-variety

AGI, HLARC, KU, RFCRC, NAFRI

CMD Was Reported in South East Asia in 2015

RESEARCH PROGRAM ON
Roots, Tubers and Bananas

Australian Government
Australian Centre for International Agricultural Research

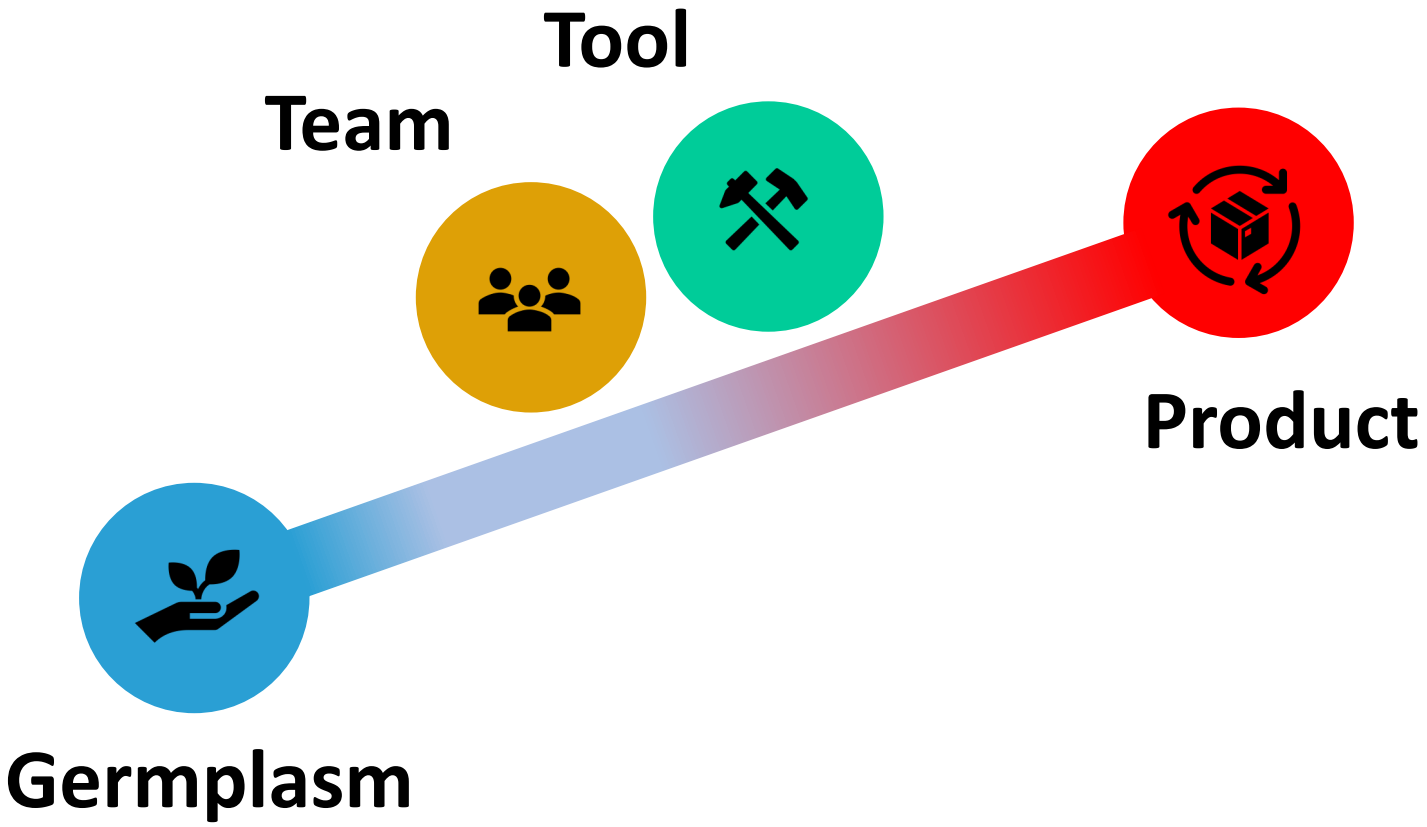
NEXTGEN CASSAVA

AIDC Your Investment Partner
Asia Investment, Development & Construction Sole Co., Ltd.

Alliance
Bioversity & CIAT

Establishing sustainable solutions to cassava diseases in mainland Southeast Asia

Objective 2: Enhance the **capacity** and **collaboration** between breeding programs in mainland Southeast Asia to develop new product profiles for commercially viable cassava varieties by **identifying** and **incorporating** known and novel sources of resistance to Cassava Mosaic Disease (CMD) and Cassava Witches Broom Disease (CWBD) into **national breeding programs**



Plant Breeding is the **genetic improvement** of **plants** for **human benefits**.

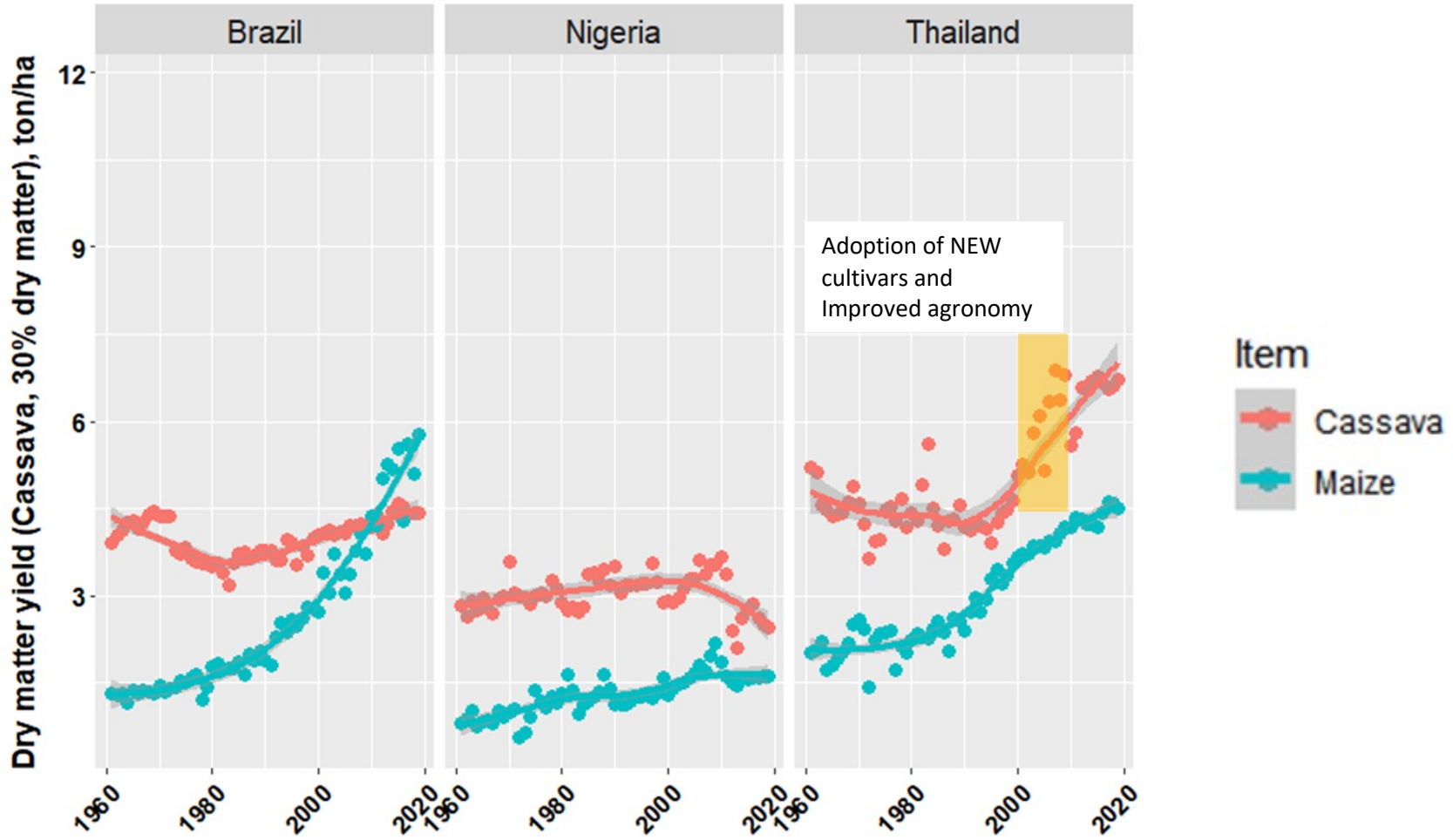
Product

High and stable dry matter cassava for South East Asia (with CMD resistance)

Target Product Profile						
Industrial cassava starch and animal feed South East Asia						
Cassava, SEA, SEA, Industrial starch and animal feed, NA, ??, ??, NA						
Cassava						
South East Asia						
South East Asia						
Laos (86,269), Cambodia (554,651), Vietnam (441,405), Thailand (1,224,459), Indonesia (128,105), Philippines (33,366)						
2,468,257						
Variety						
Subhumid lowland tropics and semi-arid lowland tropics						
	Trait	**Scale**	**Min Score**	**Trait requirement**	**Improve trait**	**Threshold trait**
CO_334:0000114	**Color**	Flesh color	1 to 3	<=2 (1, white)	Essential		Y
CO_334:0000013	**Yield**	Fresh yield	ton/ha	10% greater than commercial checks	Essential	Y	
CO_334:0000071		Starch content	%	>=25	Essential		Y
CO_334:0000138	**Agronomic traits**	Germination	%	>80	Essential		Y
CO_334:0000220		Plant vigor	1 to 5	>=3 (5, vigorous)	Essential		Y
CO_334:0000301		Lodging	1 to 3	<=2 (3, complete loging)	Essential		Y
CO_334:0000099		Plant type	1 to 5	<=3 (1, erect plant)	Essential		Y
CO_334:0000079		Branch number	count	<=5	Essential		Y
CO_334:0000018		Plant height	cm	150-350	Nice to have		
CO_334:0000106		Height of the 1st branch	cm	>100	Essential		Y
CO_334:0000123		Stem length with leaves	cm	>30cm	Nice to have		Y
CO_334:0000225		Easy harvest	1 to 3	<=2 (3, difficult to harvest)	Nice to h		
CO_334:0000223		Peduncle length (visual)	1 to 3	2 (3, long)	Esse		
CO_334:0000221		Root skin color	1 to 3	<=2 (3, brown)			
		Root type	1 to 5	<=3 (1, good root type)			
		Root		2 (3, heavy constr			

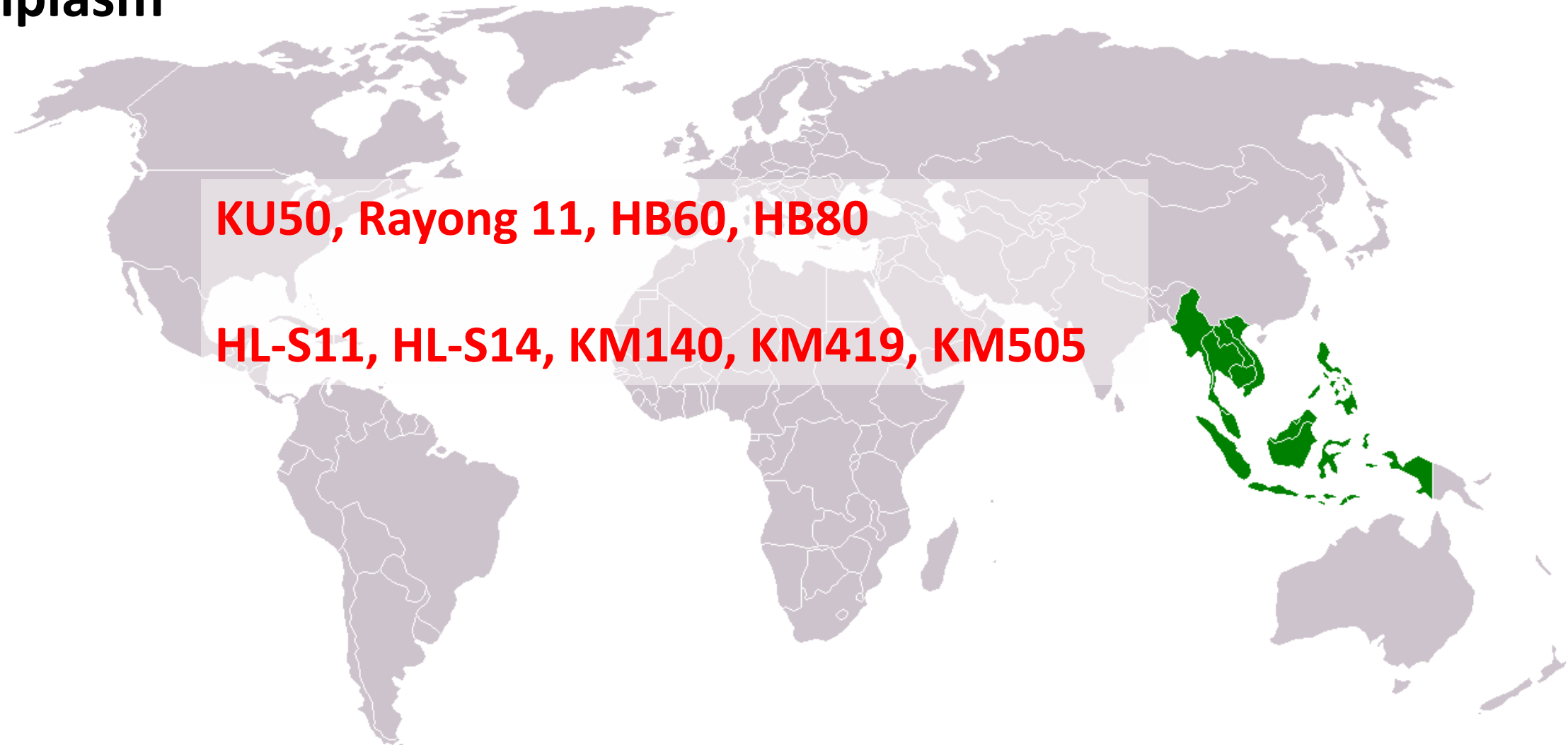
Achievements in South East Asia

Germplasm



Use Elite Varieties in South East Asia

Germplasm

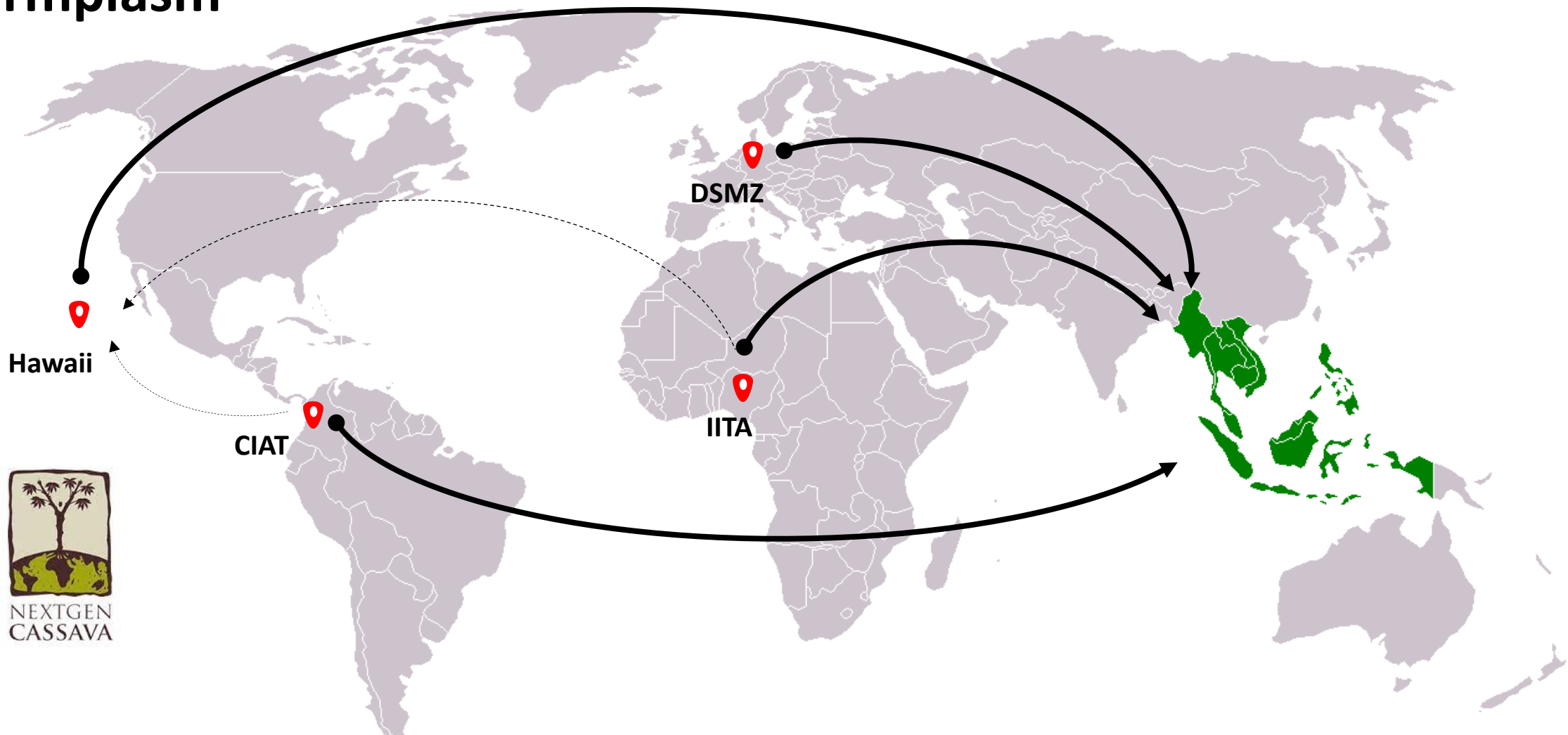


KU50, Rayong 11, HB60, HB80

HL-S11, HL-S14, KM140, KM419, KM505

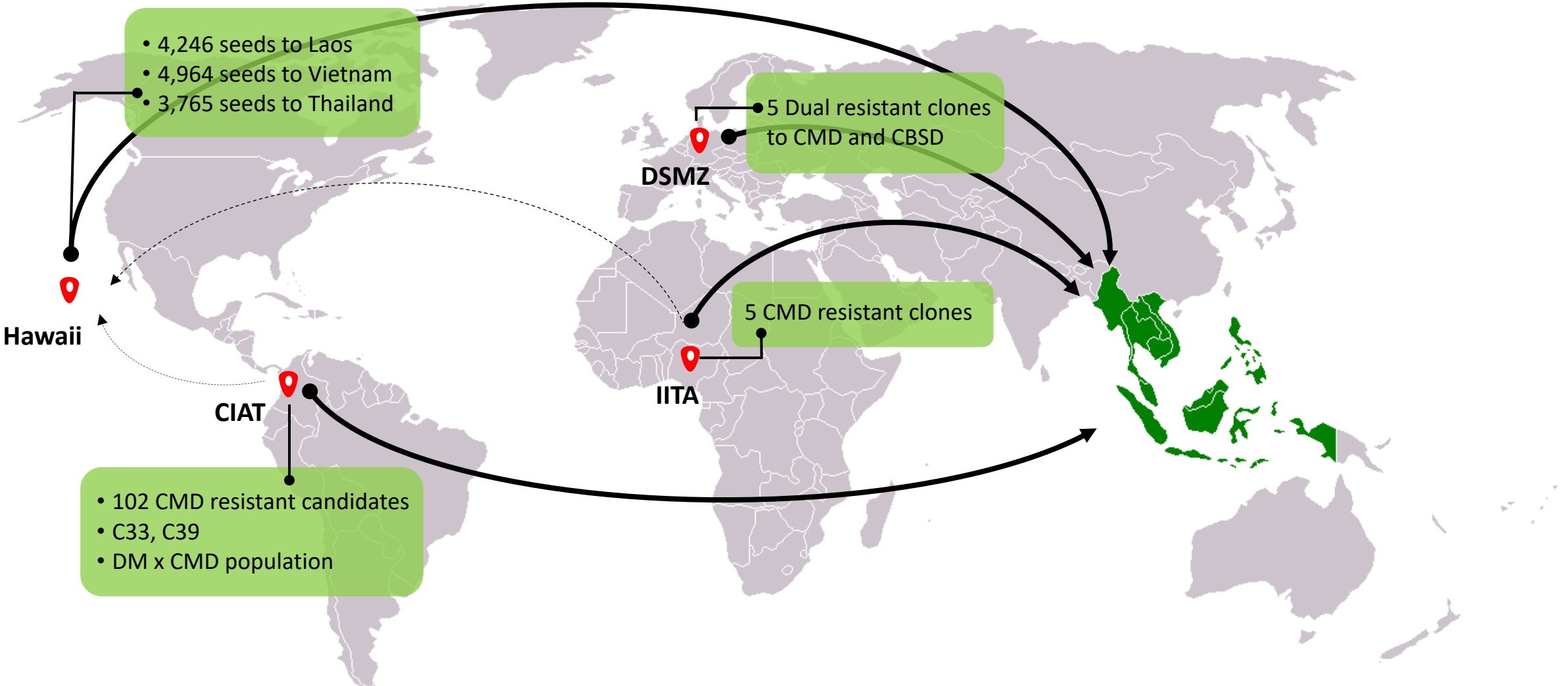
Introduce CMD-resistant Germplasm

Germplasm



NEXTGEN CASSAVA

Introduce CMD-resistant Germplasm



Team

Multidisciplinary Team

Breeding + Genetics

Agronomy

Physiology

Pathology

Seed System

Ag-economist

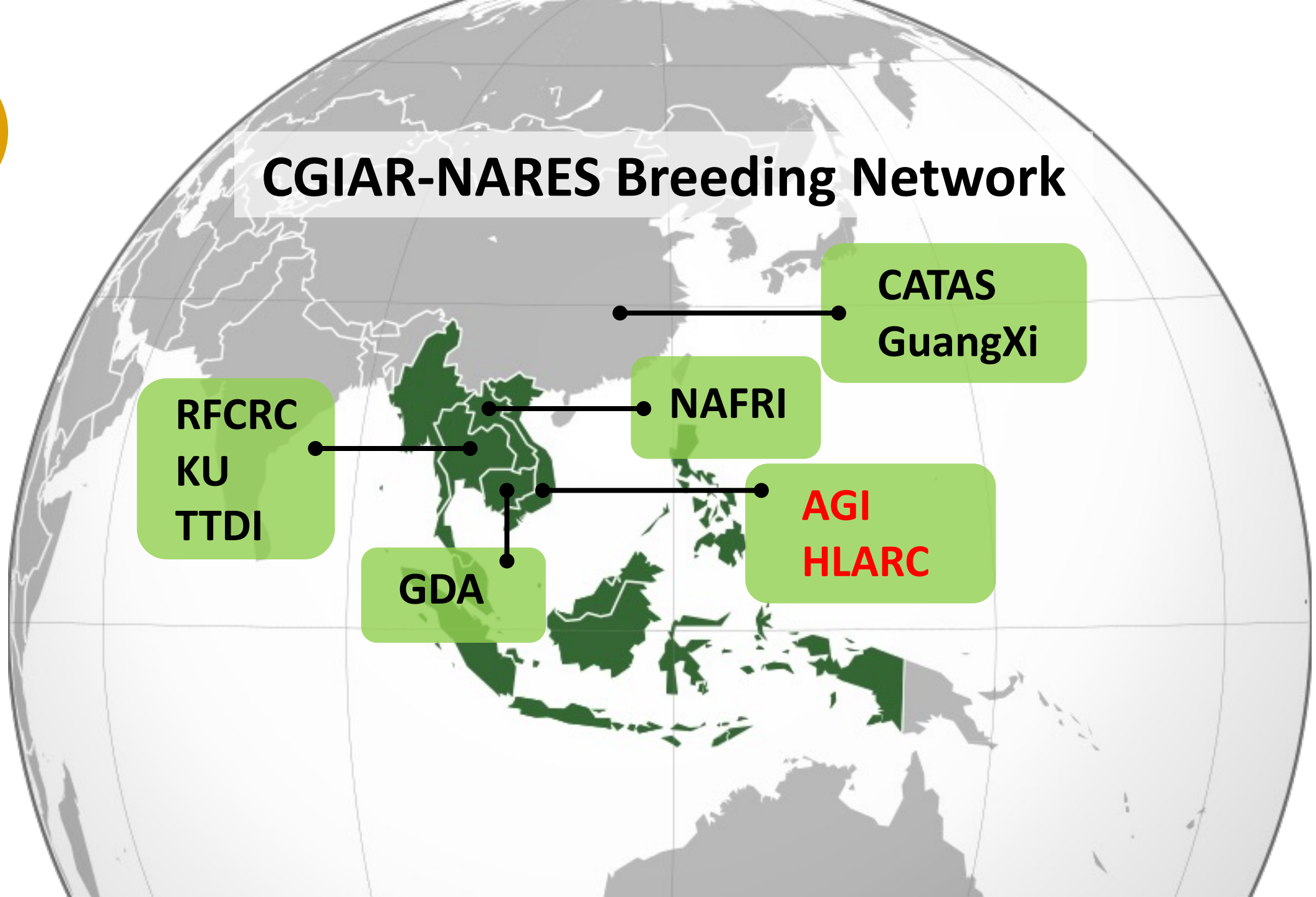
NARES

Farmer
Processor

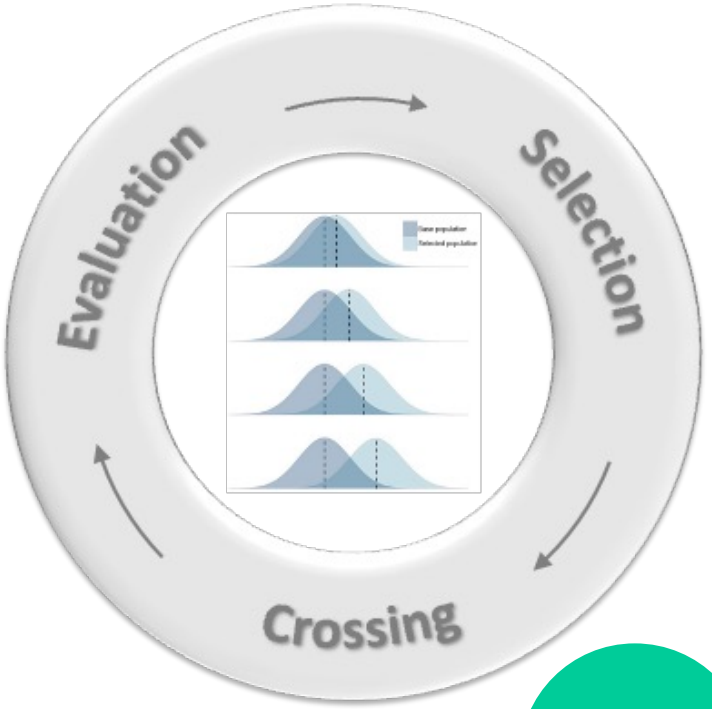
Market

Team

CGIAR-NARES Breeding Network



Tool



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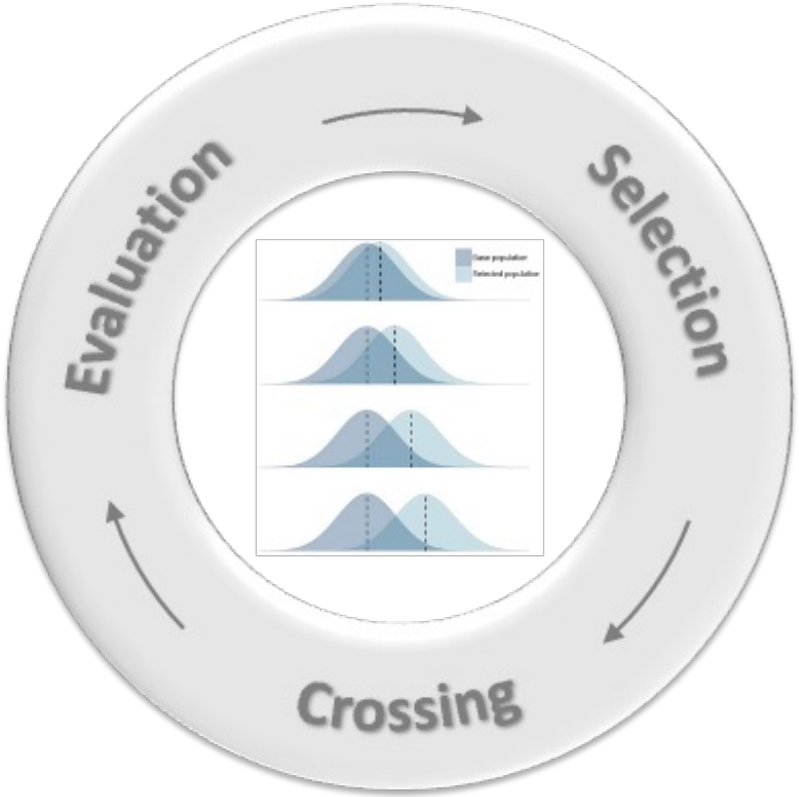


- Germplasm Introduction
- Variety Development

Breeding Trialing Network in Vietnam

1. Tay Ninh
2. Dong Nai (**HLARC**)
3. Lam Dong
4. Dak Lak
5. Phu Yen
6. Quang Ngai
7. Ha Noi (**AGI**)
8. Son La

HLARC, Hung Loc Agricultural Research Center
AGI, Agricultural Genetics Institute

Introduce CMD-resistant Germplasm in Vietnam

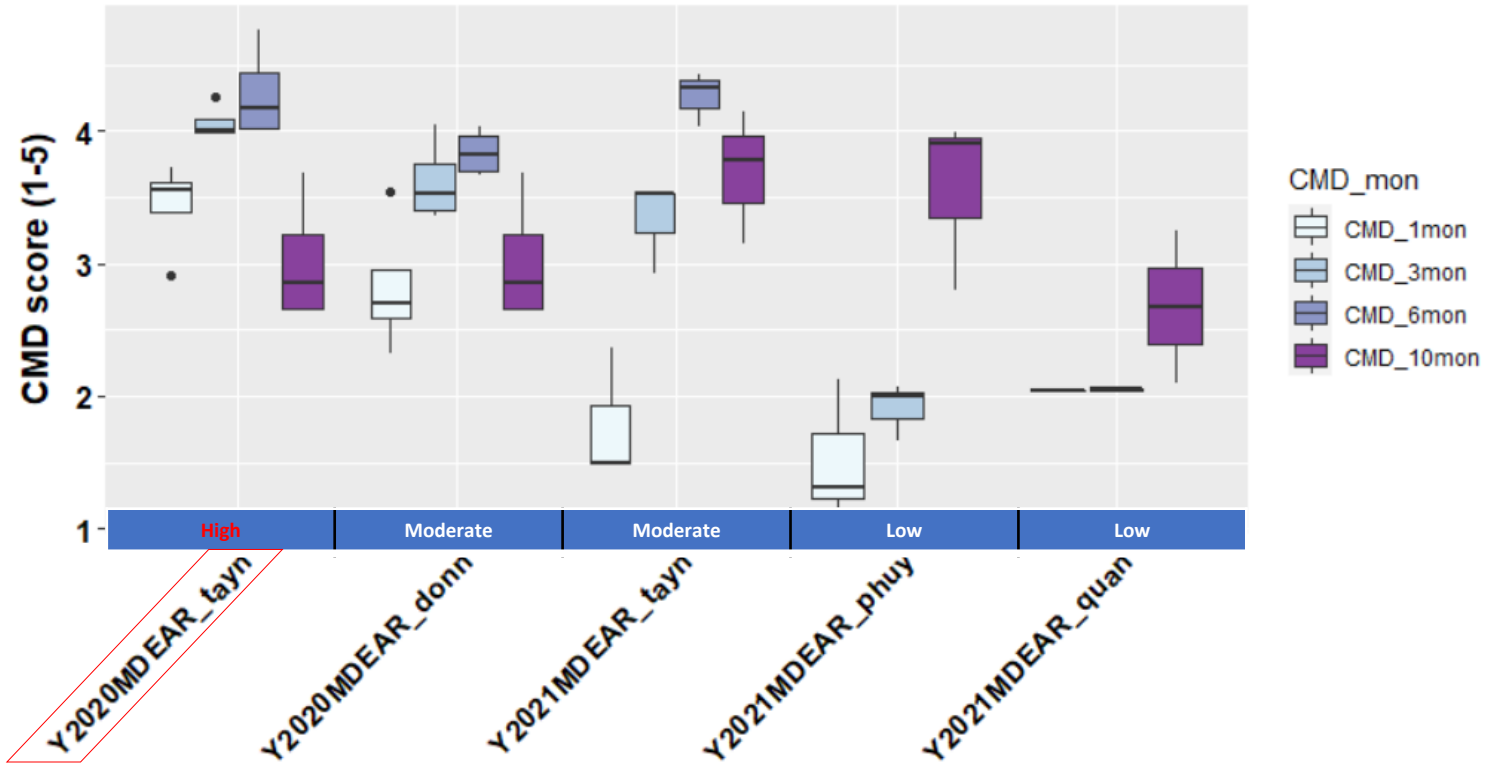
Introduction 2018-2019 CIAT and IITA	Evaluation 2019-2020 (1 loc)	AYT 2020-2021 (2 loc)	RYT 2021-2022 (6 loc)	Demonstrate & Release 2022-2023
AGI Ha Noi	Tay Ninh	*Multiplication	Tay Ninh Son La	Tay Ninh Dong Nai Quang Ngai Gia Lai Thanh Hoa Quang Tri Son La
HLARC Tay Ninh *Evaluated 142 collections from farmers' field	Tay Ninh *Evaluated collections from farmers' field	Dong Nai Tay Ninh *Imported seeds from Hawaii	Tay Ninh Dong Nai Dak Lak Phu Yen Quang Ngai	Tay Ninh Dong Nai Dak Lak Phu Yen Quang Ngai

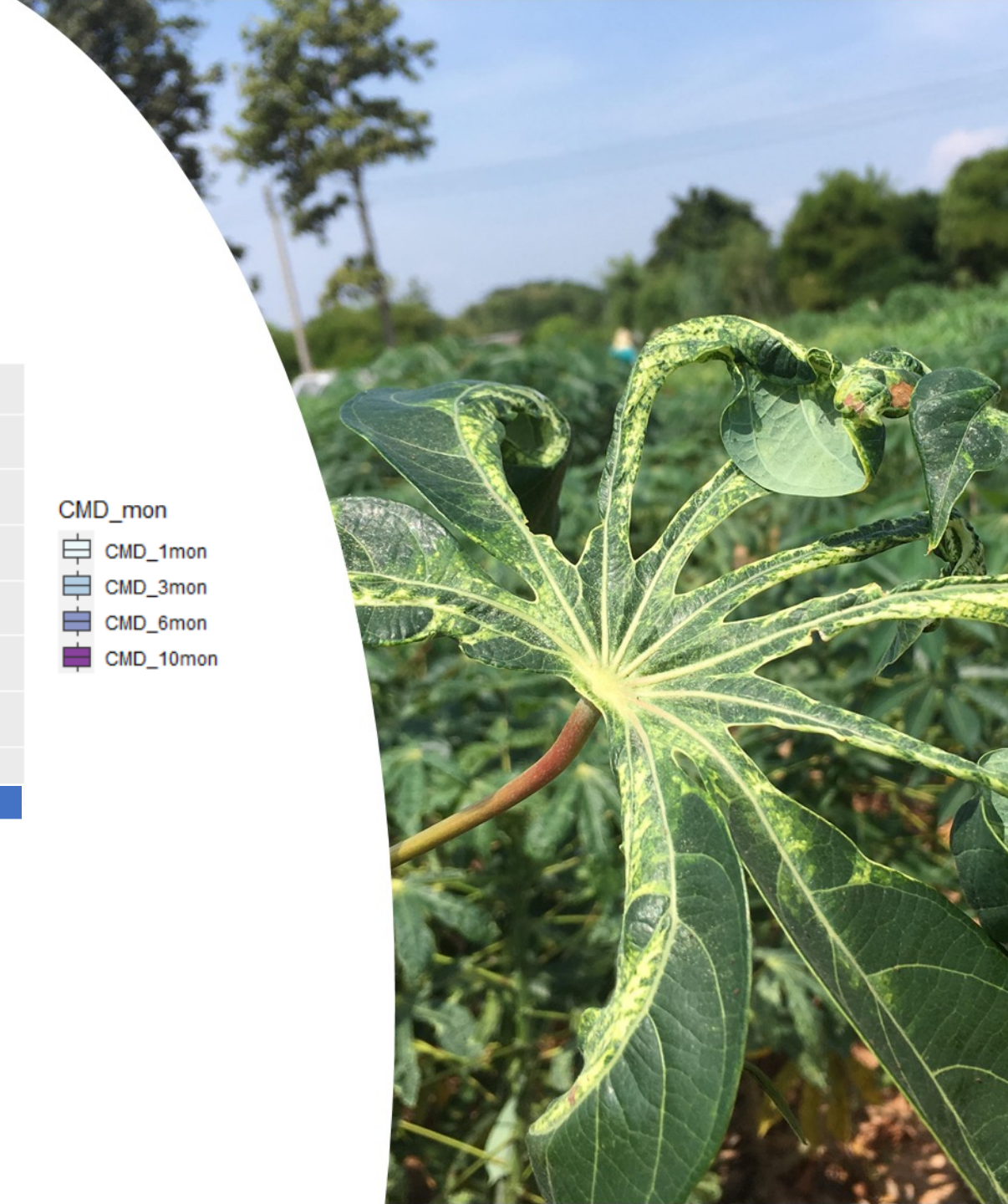
Good Yield Trial Quality – Moderate to High Heritability

trial	CMD_1mon	CMD_3mon	CMD_6mon	CMD_10mon	height	height_1st_branch	branch_number	starch	yield_v2	starch_yield	harvest_index
Y2020MDEAR_donn	0.99	0.98	0.99	0.96	0.49	0.93	0.92	0.75	0.67	0.49	NA
Y2020MDEAR_tayn	0.98	1	0.99	0.96	0.7	0.85	0.87	0.49	0.82	0.76	NA
Y2021MDEAR_phuy	0.9	0.94	NA	0.98	0.87	0.8	0.94	0.95	0.61	0.5	0.91
Y2021MDEAR_quan	1	1	NA	0.99	0.53	0.72	0.89	0.92	0.77	0.76	0.95
Y2021MDEAR_tayn	0.91	0.98	0.98	0.96	0.88	0.81	0.97	0.88	0.54	0.4	0.78

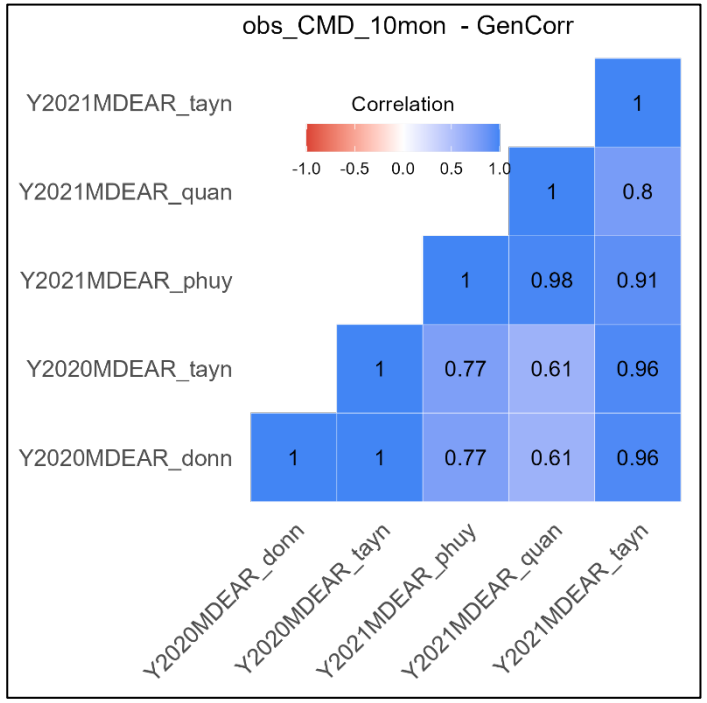
Good Poor

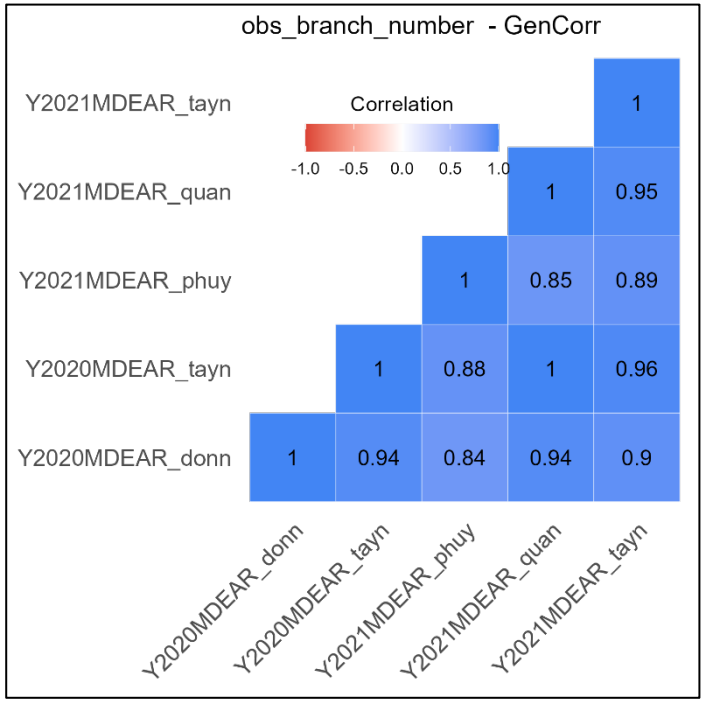
Different CMD Pressure

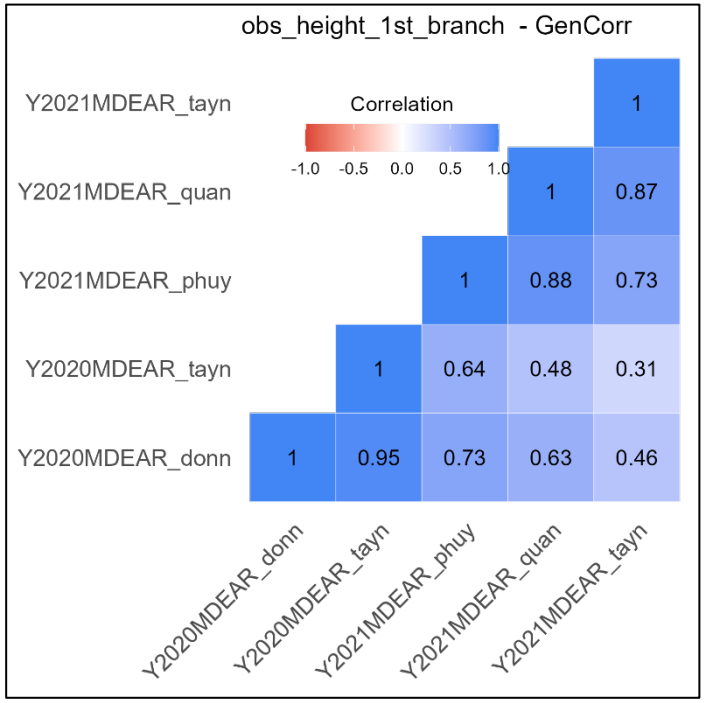




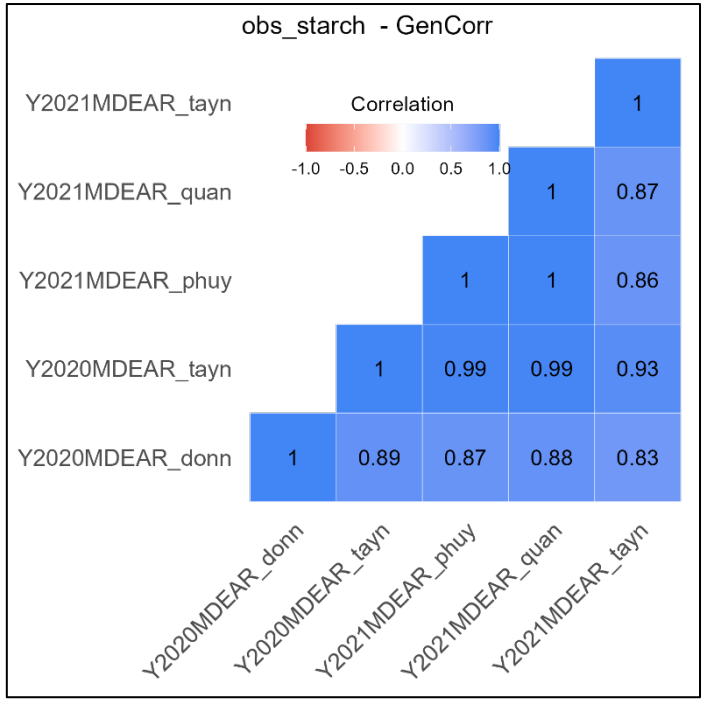
Genetic Correlation among Environments – CMD and Plant Type

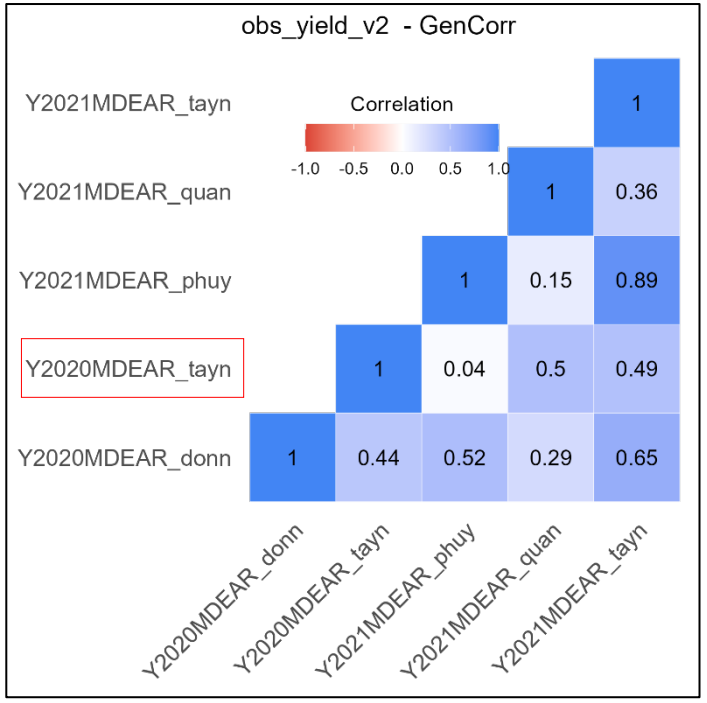


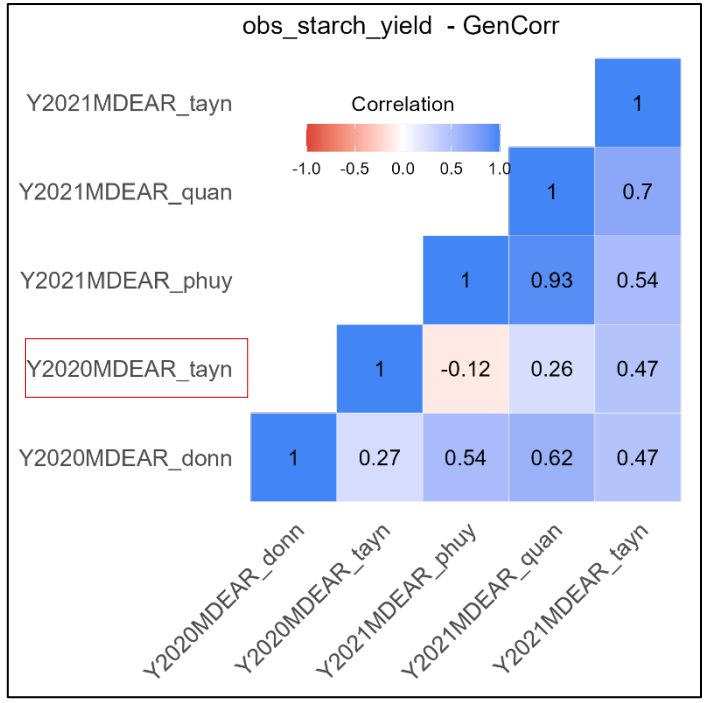




Genetic Correlation among Environments – Starch Yield







Multi-environment BLUP

-- Summary of the best clones and checks

	clone	CMD_10mon	height_1st_branch	branch_number	starch (%)	yield (ton/ha)	starch_yield (ton/ha)
	KU50	3.0	200	0.4	27.1	28.0	8.0
CIAT & IITA	TMEB419	1.1	212	0.7	24.3	30.5	7.9
CIAT & IITA	CR24-16	1.0	249	0.0	26.0	25.5	7.6
CIAT & IITA	CR13-8	1.0	190	2.5	24.5	26.8	7.2
CIAT & IITA	CR24-3	1.0	110	2.9	22.3	28.7	7.1
CIAT & IITA	CR52A-2	1.0	136	3.2	24.2	26.7	7.1
CIAT & IITA	AR9-48	1.0	204	2.4	25.4	27.5	6.7
CIAT & IITA	CR52A-4	0.9	89	3.3	27.1	24.7	6.7
CIAT & IITA	IBA980581	1.0	159	0.7	20.5	29.1	6.1
CIAT & IITA	IBA972205	1.0	98	2.8	18.5	29.1	5.9
CIAT & IITA	IBA920057	1.0	251	1.3	22.8	23.7	5.8
	IBA980505	1.0	114	2.2	18.9	23.3	5.2
	HL-S11	3.7	225	0.0	28.3	19.2	5.8
	KM140	3.5	191	0.2	21.4	22.9	5.8
	KM419	3.5	147	0.9	24.7	19.8	5.7
	KM505	2.6	215	0.6	25.8	19.9	5.3

The clones were sorted based on **starch yield**.

Good

Poor

Multi-environment BLUP

-- Summary of the best clones and checks

		BLUE – single environment mean					BLUP	BLUE – single environment mean					BLUP
		2020_donn	2020_tayn	2021_tayn	2021phuy	2021_quan	CMD_10mon	2020_donn	2020_tayn	2021_tayn	2021phuy	2021_quan	starch_yield (ton/ha)
	KU50	4.0	4.0	3.4	2.3	1.0	**3.0**	13.3	2.4	11.0	6.4	7.8	**8.0**
CIAT & IITA	TMEB419	1.0	1.0	1.4	1.3	1.0	**1.1**	7.6	13.5	10.1	4.4	9.0	**7.9**
	CR24-16	1.0	1.0	1.1	1.1	1.0	**1.0**	5.8	10.2	11.7	3.3	8.0	**7.6**
	CR13-8	1.0	1.0	1.0	1.0	1.0	**1.0**	7.0	8.5	9.4	4.4	6.1	**7.2**
	CR24-3	1.0	1.0	1.0	NA	NA	**1.0**	8.7	7.3	12.7	NA	NA	**7.1**
	CR52A-2	1.0	1.0	NA	NA	NA	**1.0**	8.7	8.9	NA	NA	NA	**7.1**
	AR9-48	1.0	1.0	1.1	1.1	1.0	**1.0**	8.1	6.6	9.6	4.5	8.6	**6.7**
	CR52A-4	0.9	0.9	0.9	NA	1.0	**0.9**	7.2	8.1	9.2	NA	6.5	**6.7**
	IBA980581	1.1	1.1	1.0	0.9	1.0	**1.0**	4.7	13.1	8.1	2.6	5.9	**6.1**
	IBA972205	1.0	1.0	0.9	1.1	1.0	**1.0**	5.5	7.7	11.6	3.8	3.1	**5.9**
	IBA920057	1.1	1.1	1.1	0.9	NA	**1.0**	5.5	4.8	10.6	4.1	NA	**5.8**
	IBA980505	1.0	1.0	NA	1.0	NA	**1.0**	4.8	6.1	NA	2.1	NA	**5.2**
	HL-S11	3.1	3.1	4.1	4.0	NA	**3.7**	11.6	1.1	7.0	3.4	NA	**5.8**
	KM140	2.7	2.7	3.1	3.9	NA	**3.5**	7.5	6.0	6.4	3.2	NA	**5.8**
	KM419	3.7	3.7	3.8	2.8	3.3	**3.5**	5.0	3.4	6.5	3.2	5.9	**5.7**
	KM505	2.6	2.6	NA	NA	2.1	**2.6**	6.4	5.6	NA	NA	6.2	**5.3**

The clones were sorted based on **starch yield**.

Varieties Released in Vietnam

CIAT & IITA

		BLUE – single environment mean					BLUP	BLUE – single environment mean					BLUP
		2020_donn	2020_tayn	2021_tayn	2021phuy	2021_quan	starch_yield (ton/ha)	2020_donn	2020_tayn	2021_tayn	2021phuy	2021_quan	starch (%)
	KU50	13.3	2.4	11.0	6.4	7.8	**8.0**	28.4	28.2	27.2	24.1	29.1	**27.1**
HN1	TMEB419	7.6	13.5	10.1	4.4	9.0	**7.9**	26.8	29.7	25.3	20.0	24.1	**24.3**
HN36	CR24-16	5.8	10.2	11.7	3.3	8.0	**7.6**	27.1	30.9	27.0	22.5	27.2	**26.0**
	CR13-8	7.0	8.5	9.4	4.4	6.1	**7.2**	25.9	29.5	25.6	20.8	25.3	**24.5**
	CR24-3	8.7	7.3	12.7	NA	NA	**7.1**	22.5	27.7	24.7	NA	NA	**22.3**
	CR52A-2	8.7	8.9	NA	NA	NA	**7.1**	23.8	30.7	NA	NA	NA	**24.2**
HN97	AR9-48	8.1	6.6	9.6	4.5	8.6	**6.7**	25.8	25.8	25.9	23.2	25.8	**25.4**
	CR52A-4	7.2	8.1	9.2	NA	6.5	**6.7**	26.8	29.6	29.3	NA	26.9	**27.1**
HN80	CR27-20	8.9	7.4	8.9	NA	4.6	**6.5**	25.9	30.4	26.5	NA	26.4	**26.3**
HN5	IBA980581	4.7	13.1	8.1	2.6	5.9	**6.1**	21.0	27.1	20.5	18.0	19.8	**20.5**
HN3	IBA972205	5.5	7.7	11.6	3.8	3.1	**5.9**	21.4	26.1	21.0	12.8	14.2	**18.5**
	IBA920057	5.5	4.8	10.6	4.1	NA	**5.8**	22.0	25.8	26.6	19.0	NA	**22.8**
	IBA980505	4.8	6.1	NA	2.1	NA	**5.2**	21.4	23.5	NA	14.8	NA	**18.9**
	HL-S11	11.6	1.1	7.0	3.4	NA	**5.8**	29.0	29.1	27.6	27.1	NA	**28.3**
	KM140	7.5	6.0	6.4	3.2	NA	**5.8**	21.3	27.1	23.3	17.9	NA	**21.4**
	KM419	5.0	3.4	6.5	3.2	5.9	**5.7**	23.8	30.7	23.8	22.5	23.0	**24.7**
	KM505	6.4	5.6	NA	NA	6.2	**5.3**	25.8	31.3	NA	NA	27.9	**25.8**

The clones were sorted based on **starch yield**.

Share CMD-resistant Germplasm in Southeast Asia

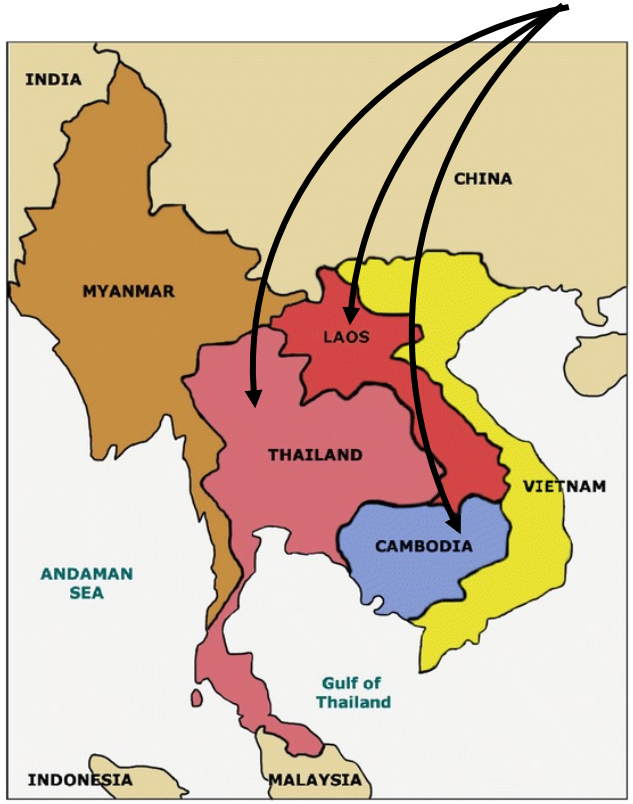
Introduction
2018-2019
CIAT and IITA

Evaluation
2019-2020
(1 loc)

AYT
2020-2021
(2 loc)

RYT
2021-2022
(6 loc)

Demonstrate & Release
2022-2023



- The CMD-resistant clones with the best agronomic performance from CIAT and IITA were shared with **Thailand, Laos and Cambodia**.
- The tissue culture plantlets were sent from **AGI or CIAT**
- **Yield trials** were established in 2023**.**

Population from Hawaii

2020-2021	2021-2022	2022-2023	2023-2024
Seedlings	Single-row plot	PYT	AYT
4,964 seeds’ 639 seedlings	175 clones	17 clones	6 clones

Performance of the Population from Hawaii in PYT

genotype			BLUPs_germination_perc		BLUPs_starch		BLUPs_yield_ha		BLUPs_starch_yield	
	check	advanced	Tai Ninh	Dong Nai	Tai Ninh	Dong Nai	Tai Ninh	Dong Nai	Tai Ninh	Dong Nai
KM505	yes		1.0	1.0	23.8	23.8	28.0	17.0	6.5	4.5
KU50	yes		0.9	0.9	21.6	20.9	28.0	23.4	5.8	5.4
TMEB419	yes		1.0	1.0	16.8	21.3	28.8	26.3	4.7	5.8
VN19-1050	yes		0.9	0.9	11.6	17.2	31.5	14.9	3.4	3.2
IBA980581	yes		0.4	0.4	14.9	13.8	15.3	6.8	2.3	1.1
CR24-16	yes		0.5	0.2	20.3	14.5	9.5	-0.5	2.1	0.3
HLH20-H0016		yes	0.9	0.8	20.8	20.2	32.6	13.2	6.5	3.4
HLH20-H0085		yes	0.9	0.4	20.0	18.9	31.9	7.8	6.2	1.8
HLH20-H0108		yes	0.9	0.8	18.6	15.1	34.1	8.1	6.1	1.7
HLH20-H0022		yes	0.8		22.9		26.2		5.8	
HLH20-H0047		yes	0.9	0.9	17.8	18.6	32.4	21.6	5.7	4.3
HLH20-H0075		yes	0.8	0.4	18.7	16.7	30.8	1.3	5.6	0.8
HLH20-H0135			0.8		18.8		27.0		5.1	
HLH20-H0039		yes	0.9	0.9	12.1	9.0	45.5	28.9	4.8	1.8
HLH20-H0036			0.7	0.3	19.0	16.3	22.7	4.9	4.2	1.1
HLH20-H0038			0.9		17.5		23.5		4.0	
HLH20-H0051			0.5	0.3	18.8	15.7	21.6	5.9	4.0	0.4
HLH20-H0082			0.5	0.0	19.4		11.6	0.0	2.5	0.0
HLH20-H0031			0.6	0.2	19.9	16.6	9.3	0.5	2.2	0.3
HLH20-H0050			0.3	0.4	16.6	13.8	10.7	5.6	1.9	0.7
HLH20-H0065			0.5	0.2	20.4	18.4	5.4	1.6	1.2	0.3
HLH20-H0053			0.1	0.0		16.6		1.7		0.6
HLH20-H0083			0.0	0.1				0.0		0.0

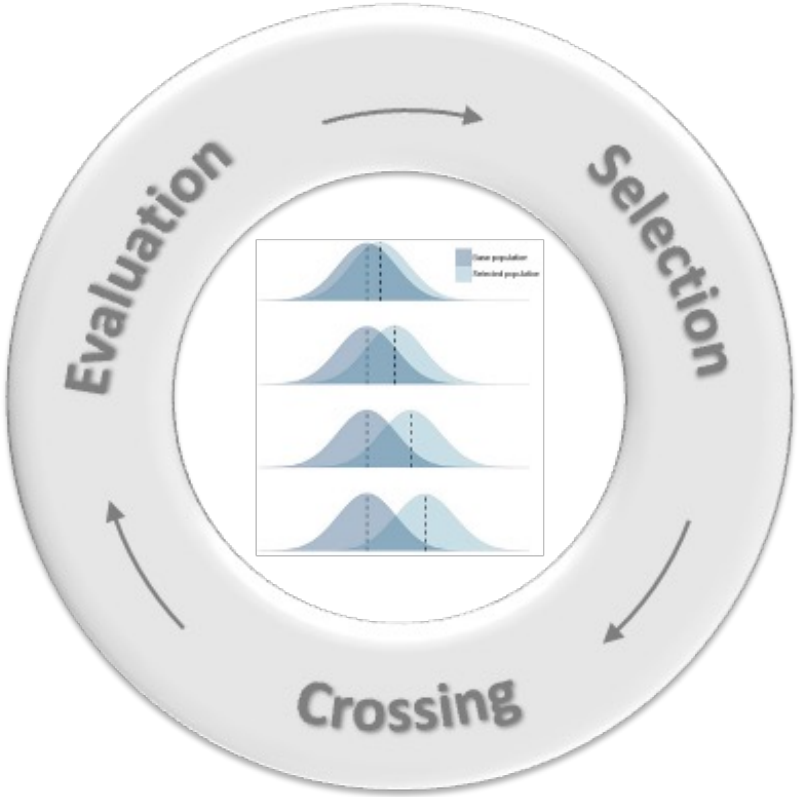
Summary of Introduced Germplasm

- ***HN1 (TMEB419) is a widely adaptable line*** with good resistance to CMD and good fresh tuber yield and starch content.

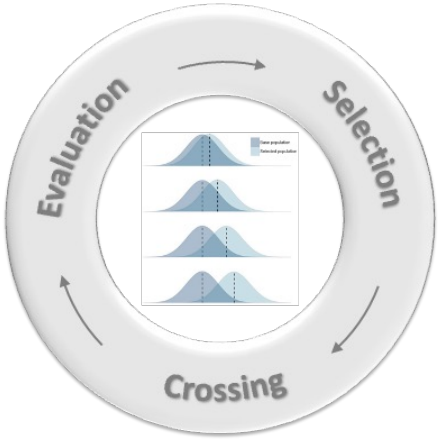
- From 2022 until now, HN1 (TMEB419) has been planted in more than ***6,000 hectares***.

- ***Further improvement is required*** in starch stability, plant type, other pest and disease resistance

Tool

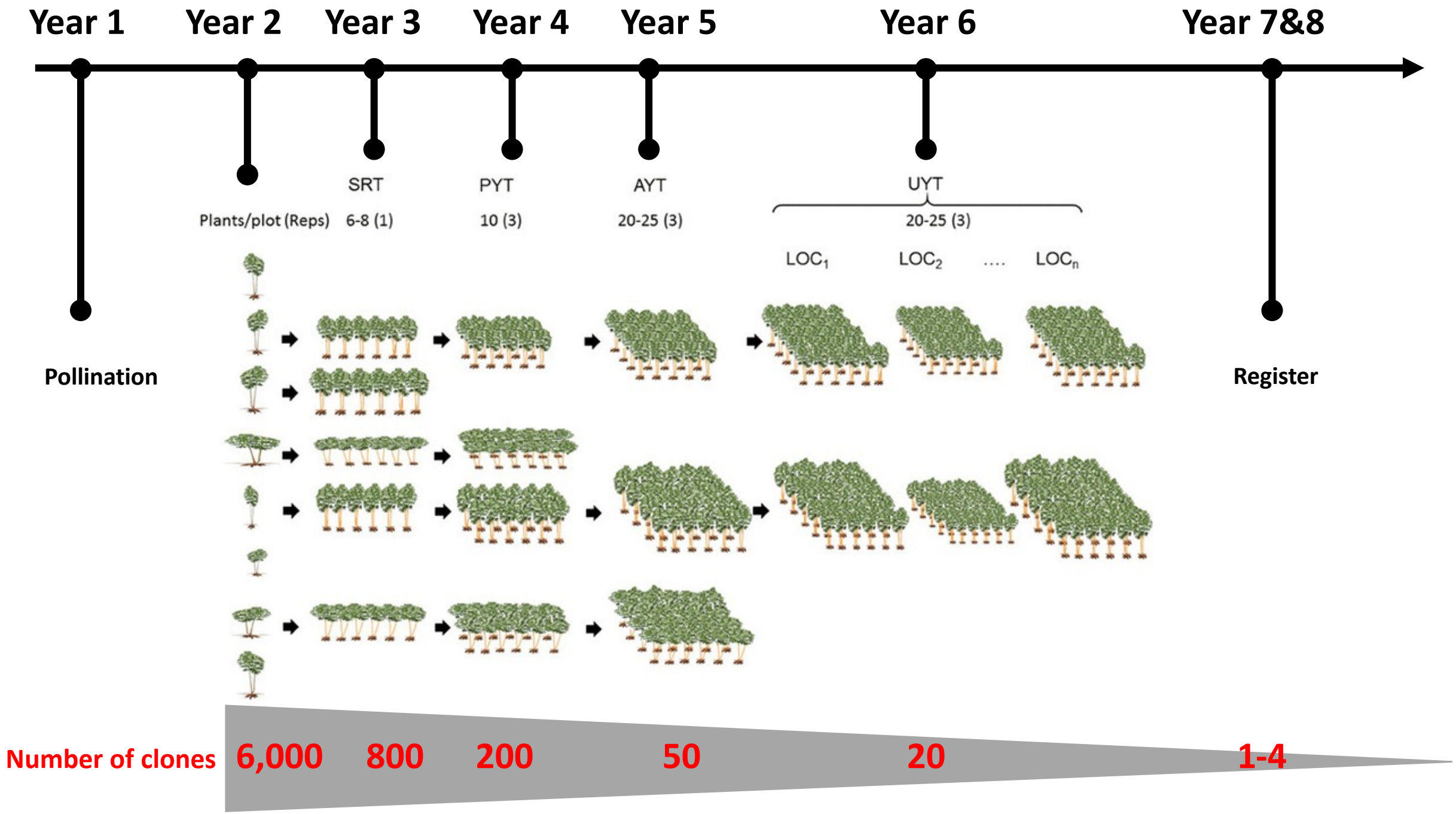


- Germplasm Introduction
- **Variety Development**



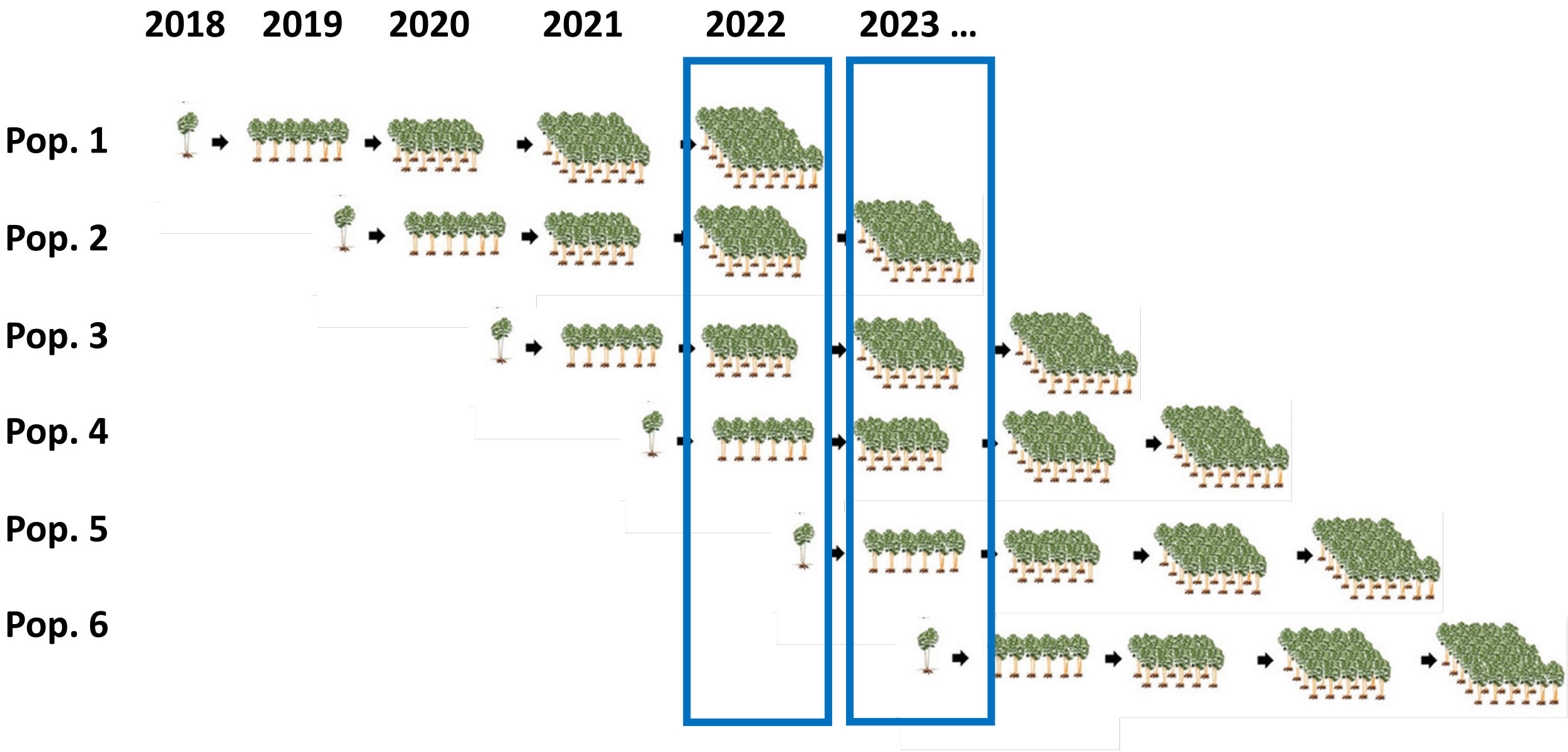
Breeding process
– One breeding population

Multiple years of evaluation to confirm the stable performance cross years


Year 1
Year 2
Year 3
Year 4
Year 5
Year 6
Year 7&8
SRT
PYT
AYT
UYT
Plants/plot (Reps)
6-8 (1)
10 (3)
20-25 (3)
20-25 (3)
LOC1
LOC2
....
LOCn
Pollination
Register
Number of clones
6,000
800
200
50
20
1-4

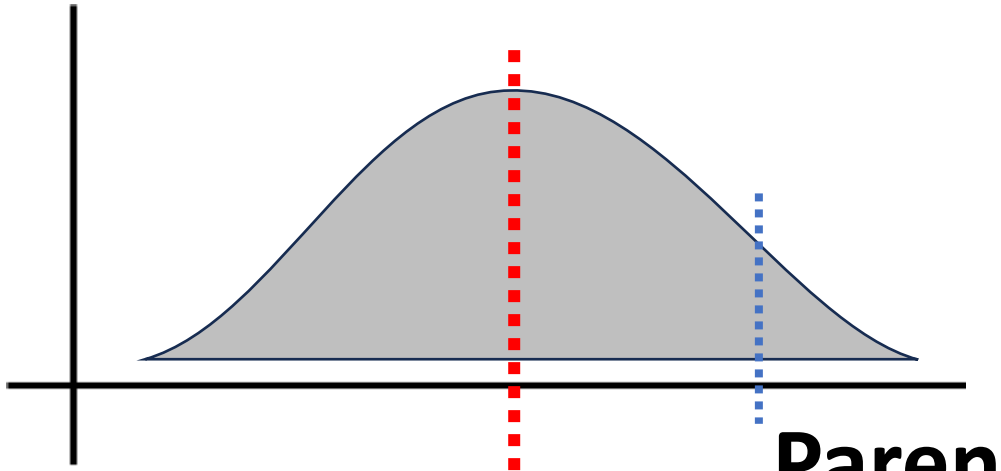
Breeding process

– Multiple populations simultaneously



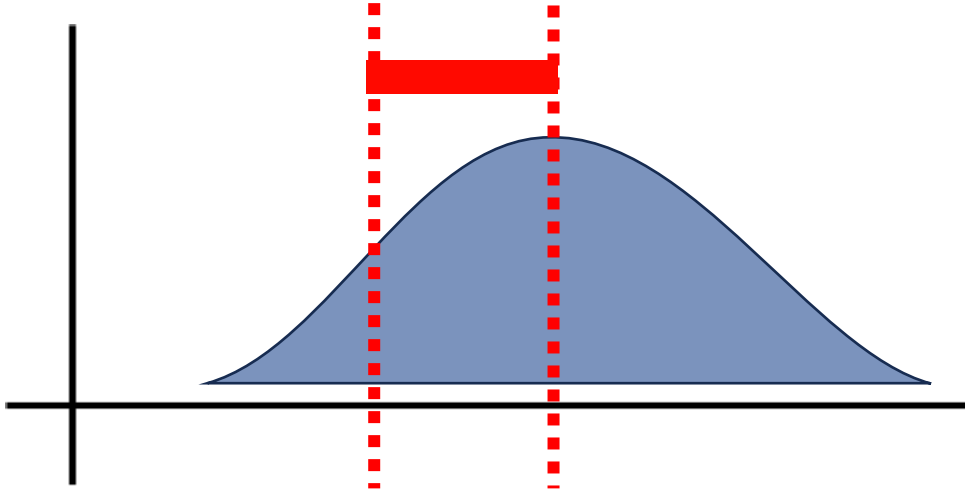
Every year, we have all breeding stages to identify the best clones

Parental generation



Parents

Progeny generation



Improvement

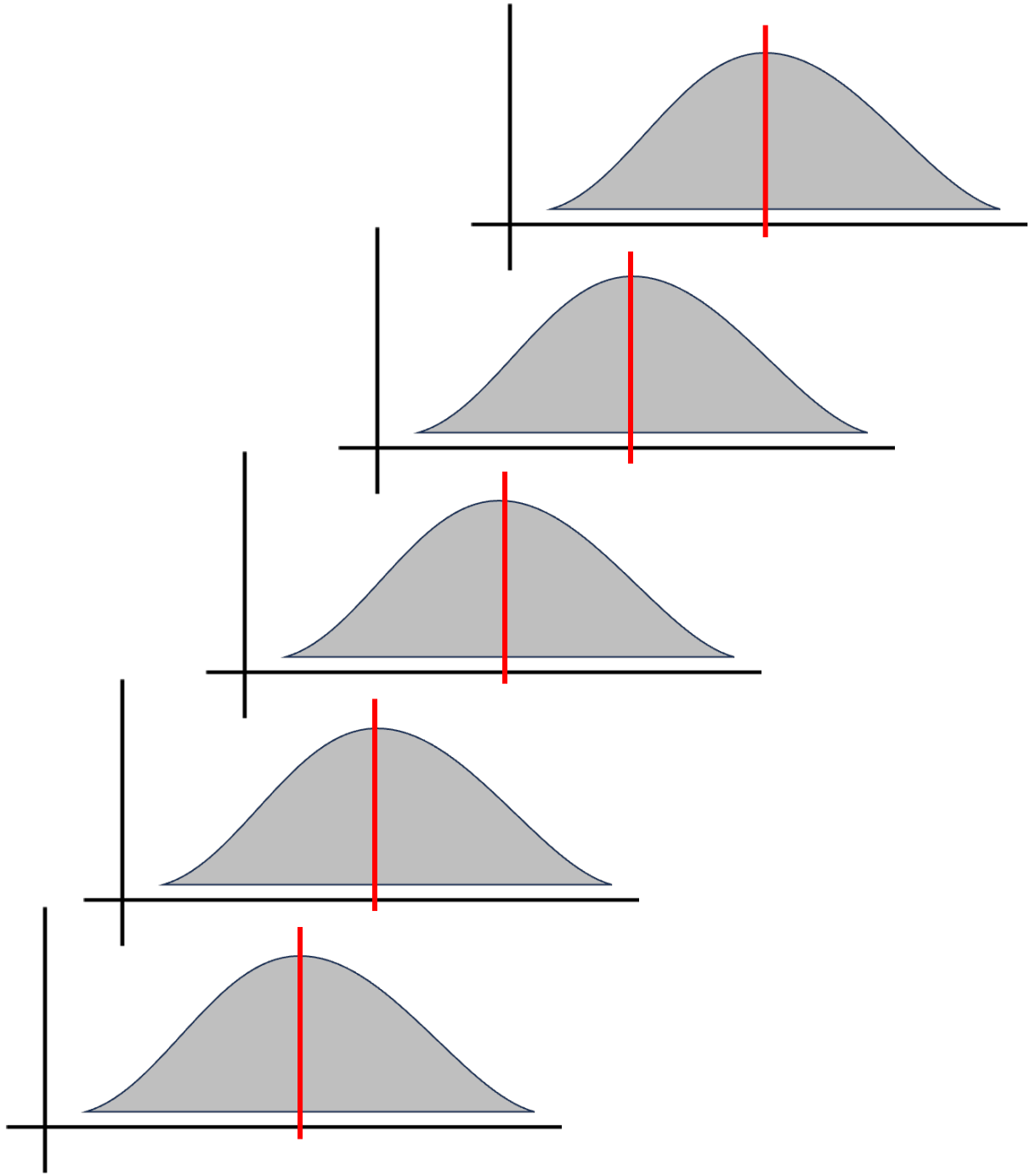
Generation 4

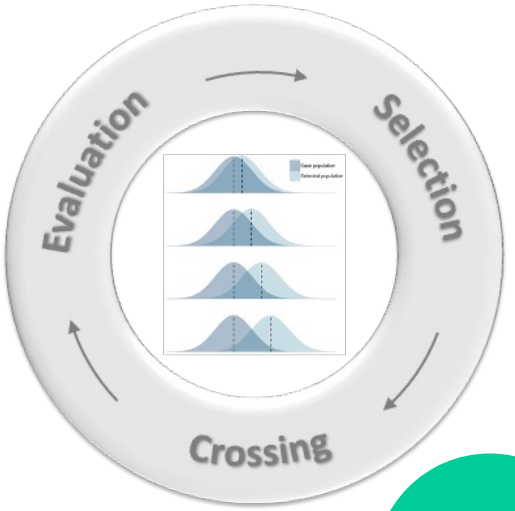
Generation 3

Generation 2

Generation 1

Generation 0




Evaluation
Selection
Crossing

Develop CMD-resistant Varieties in Vietnam

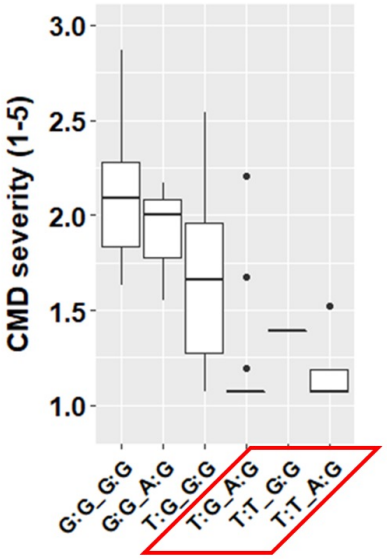
Introduction 2018-2019 CIAT and IITA → **Evaluation** 2019-2020 (1 loc) → **AYT** 2020-2021 (2 loc) → **RYT** 2021-2022 (6 loc) → **Demonstrate & Release** 2022-2023

2020-2021 **Crossing Nursery**

2021-2022 **Seedling Trial**
3,000 seeds; 2 loc
CMD2 markers

2022-2023 **Single Row trial**
200 clones; 2 loc

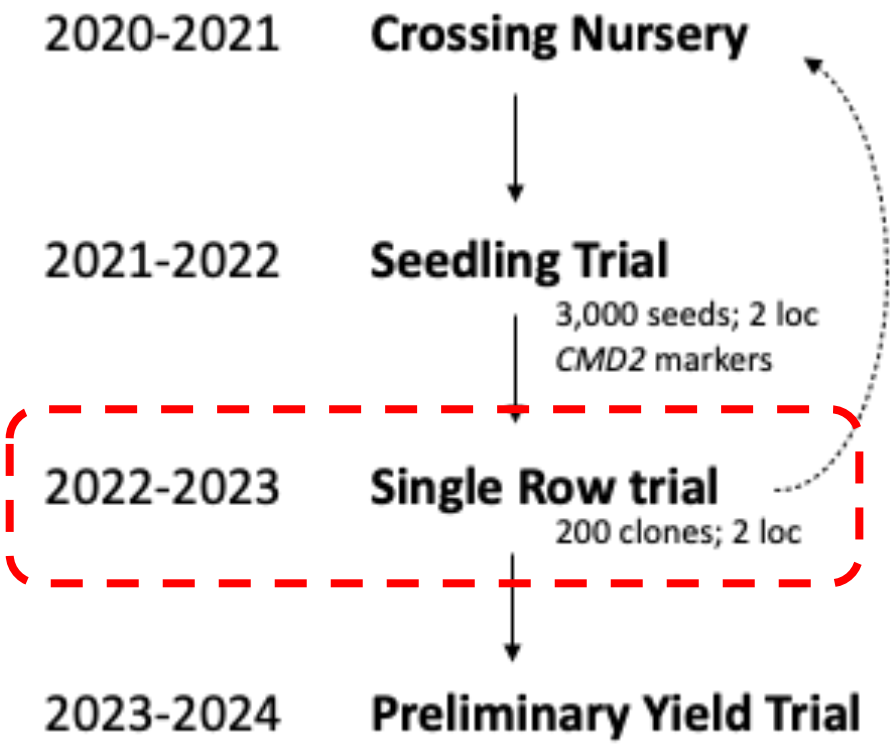
2023-2024 **Preliminary Yield Trial**



Validated and Implemented *CMD2* markers

Photoperiod extension induces early flowering

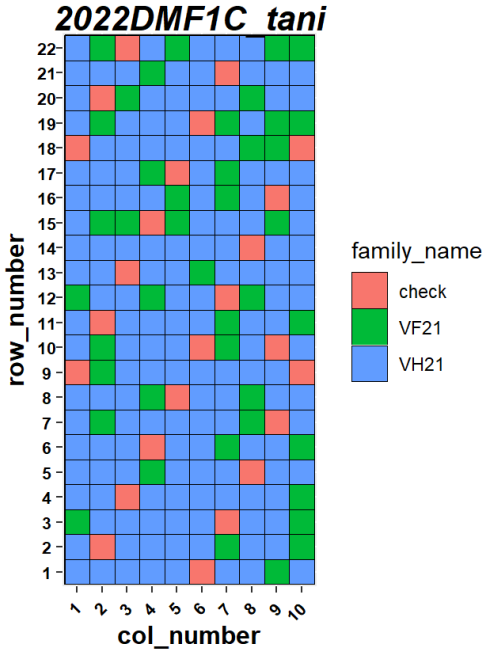
Single-Row Trial Evaluation of the Breeding Population



Broad-sense Heritability at Two Locations

	CMD (6 mon)	Branch number	Starch content	Yield per ha
Two loc.	0.87	0.66	0.7	0.38

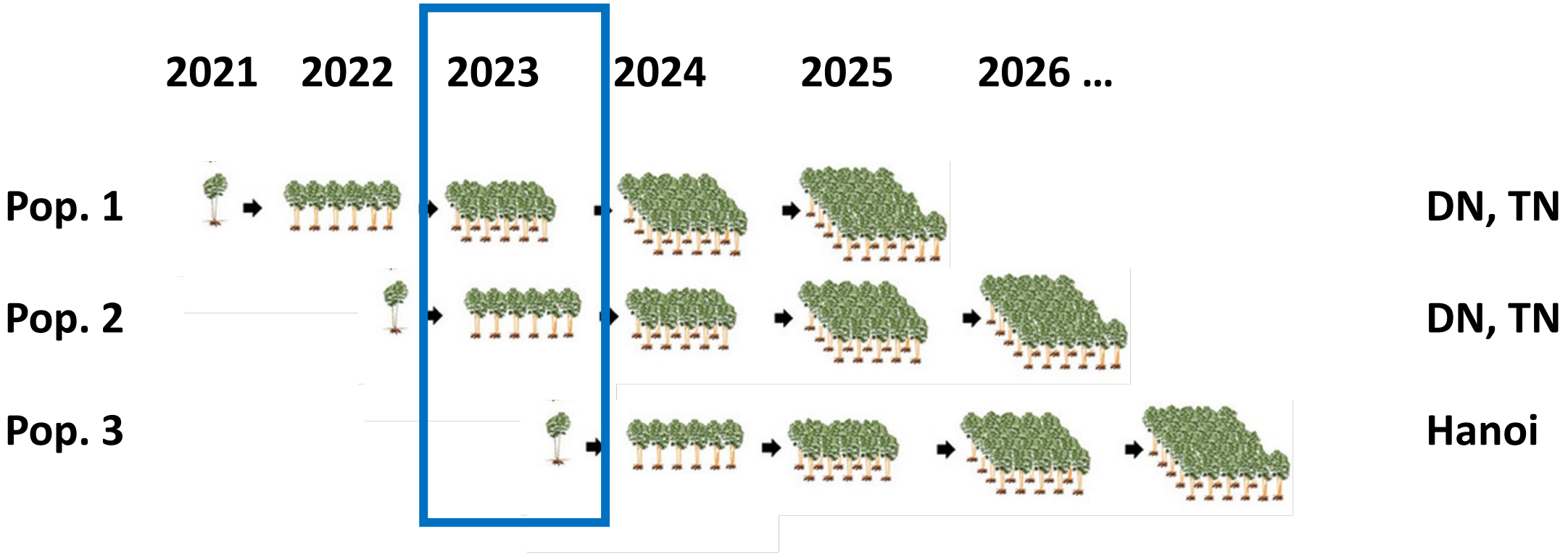
2022-2023 growth season



Selected Progenitors for the Next Cycle

accession_name	pedigree	height_1st_branch (cm)	yield (ton/ha)	starch_content (%)	starch yield (ton/ha)
VH21-0127	IBA980505	200.4	34.6	22.0	7.63
VH21-0779	KU50	160.4	30.4	24.2	7.37
VH21-0097	IBA972205	150.1	28.9	23.9	6.91
VF21-0055	HLS14_AR9-18	184.0	28.9	22.9	6.60
VF21-0005	HLS13_CR24-3	214.3	26.5	24.7	6.54
VH21-0061	IBA972205	260.0	29.1	22.2	6.46
VH21-0447	AR9-18	235.2	27.0	23.9	6.46
VH21-0402	KM140	177.8	28.3	22.7	6.43
VF21-0197	KM419_AR9-18	167.5	29.7	21.7	6.43
VF21-0146	KM140_AR9-18	262.7	27.7	23.1	6.40
VH21-0016	IBA920057	229.9	27.6	22.4	6.18
VH21-0729	KU50	303.3	25.5	23.6	6.01
TMEB419		285.9	25.9	24.9	6.45
KU50		253.6	26.3	23.4	6.14

Three Populations of Cycle 1 in the Field

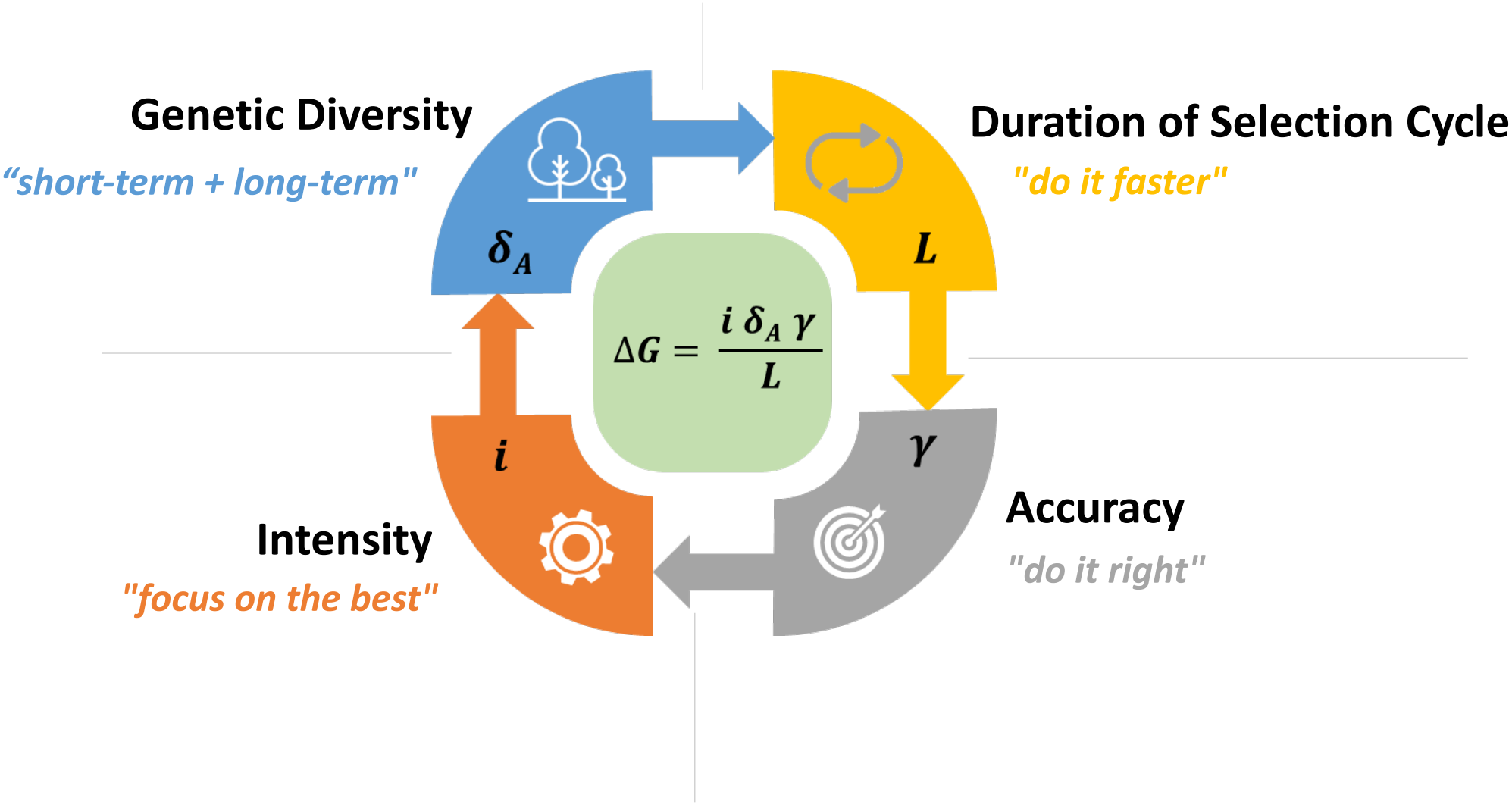


The crossing nursery for cycle 2 is in Lam Dong.

Breeding Populations of Three Cohort of Cycle 1 (2021-20223)

Item	2021	2022	2023
Number seed sowing			
Full-sibs (seed)	1.874	1.556	1.844
Half-sibs (seed)	5.290	3.712	4.040
Germination (%)			
Full-sibs	38.40	55.40	60.85
Half-sibs	26.74	44.80	45.50
Clones to testing CMD marker			
Full-sibs (clone)	137	303	
Half-sibs (clone)	93	499	
Showing have CMD2			
Full-sibs (clone)	61	158	
Half-sibs (clone)	48	160	
Single row evaluation clones	336	319	

Increase **Genetic Gains** through **Continuous Improvement**



Continuous Improvement

Genetic Diversity

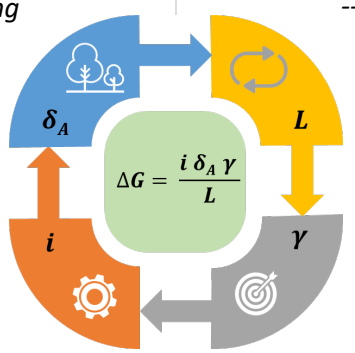
- Variation profiling (2022-)
- Hybrid Breeding (2019-)

-- Selfing

Duration of Selection Cycle

- **Early flowering** (2016-)
- Genomic Selection (2019-)

-- Mate and parent selection



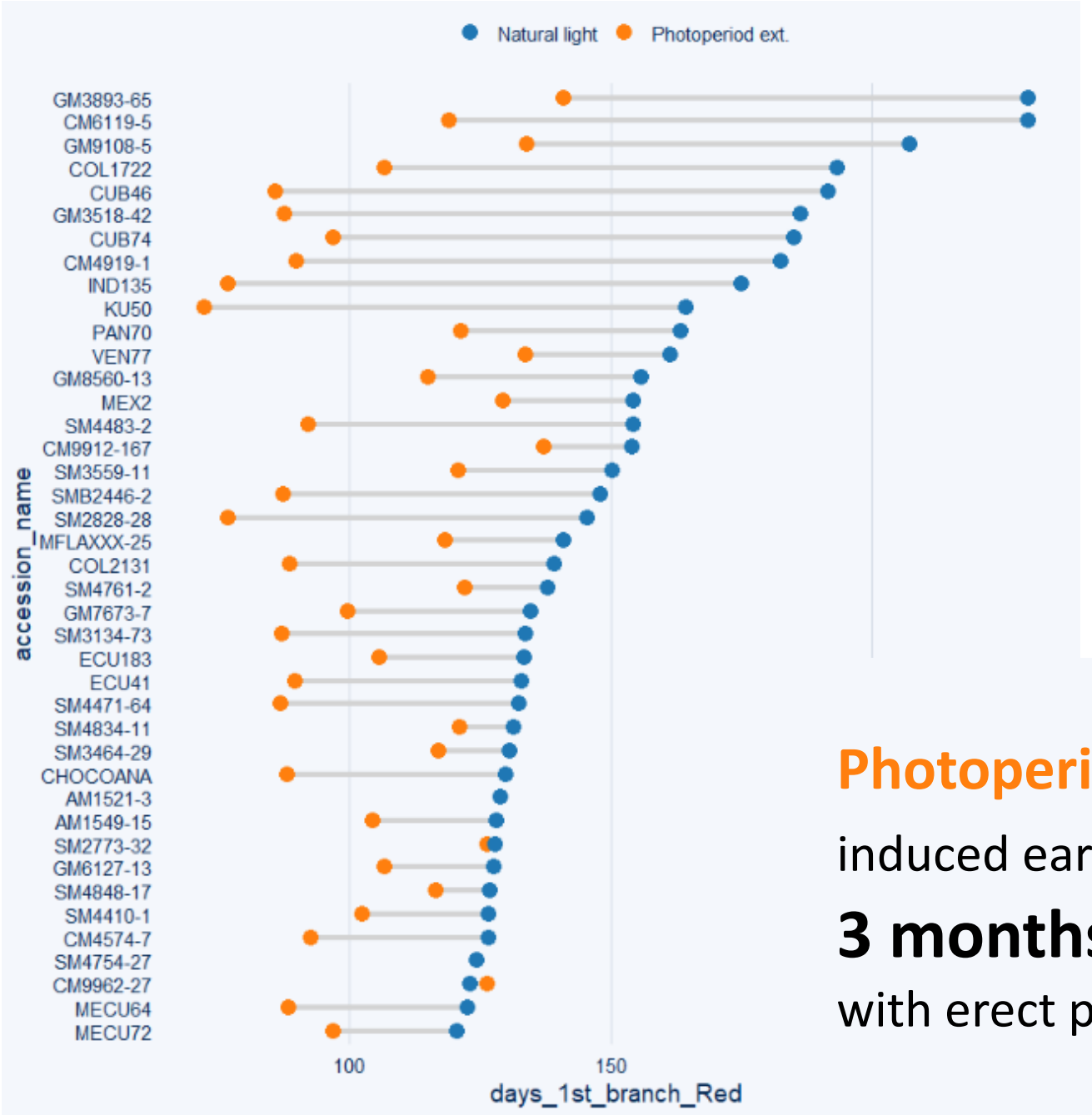
Intensity

- GeoRadar for yield (2022-)
- QualitySpec for WAB (2022-)
- Hyperspectral imaging (2022-)
- Drone imaging for early vigor (2022-)
- Imaging for whitefly (2018-)
- Imaging for PPD (2019-)

Accuracy

- **Digitalization** (2019-)
- ≥ 5 Checks, BLUP and GBLUP (2020-)
- Selection Index (2012-)
- NIRS & Image Analysis (2012-)
- Operational Excellence (SOP) (2019-)
- QC/QA (2020-)
- **MAS** (2020-)

*-- **CMD**, CBSD, DM, **carotenoid**, HCN, WAB, sprouting, ID, flowering, mites, thrips, small granule, plant type*

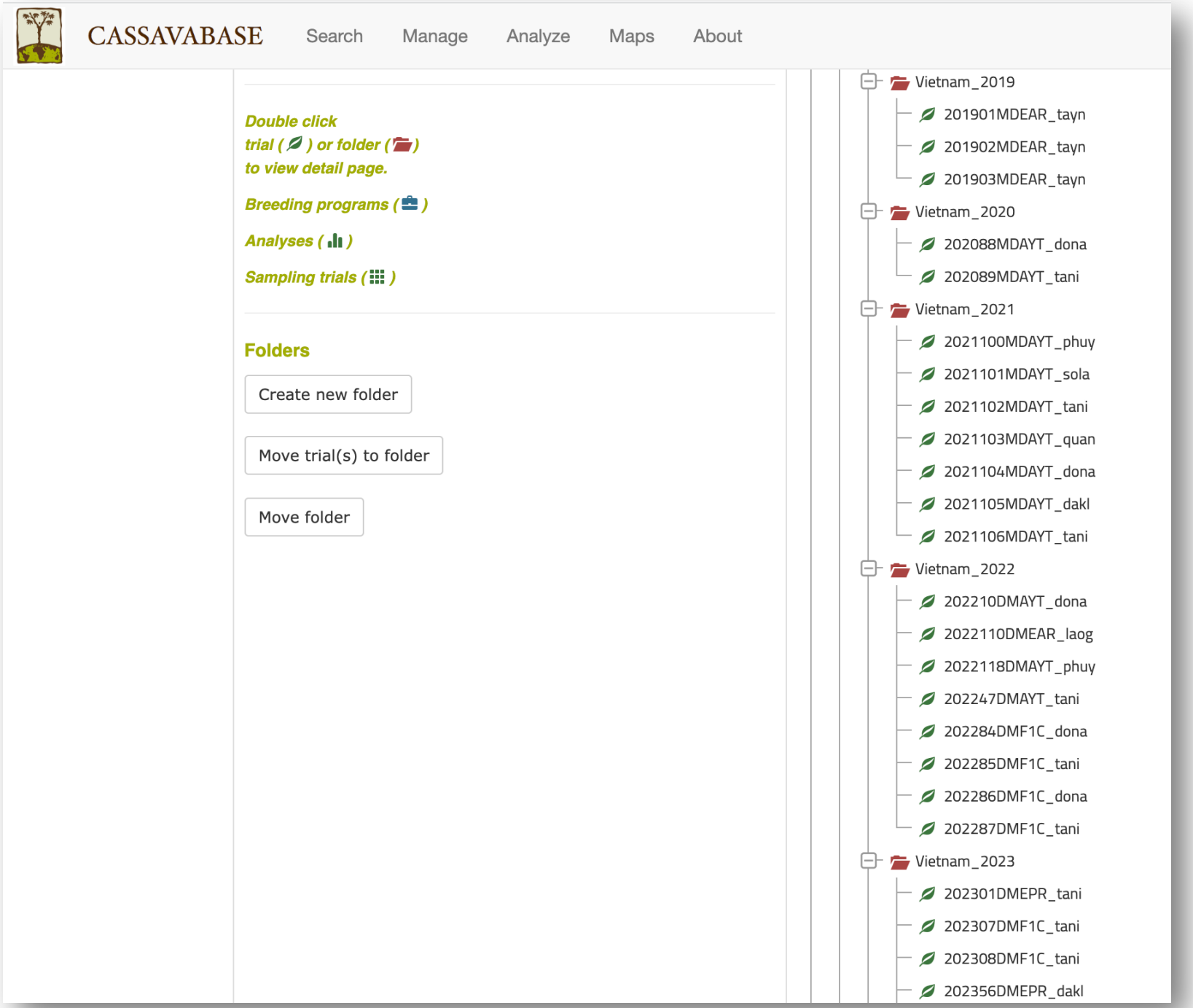


Photoperiod Extension

induced early flowering by **2-3 months** for progenitors with erect plant architecture.

Data Management

Fieldbook

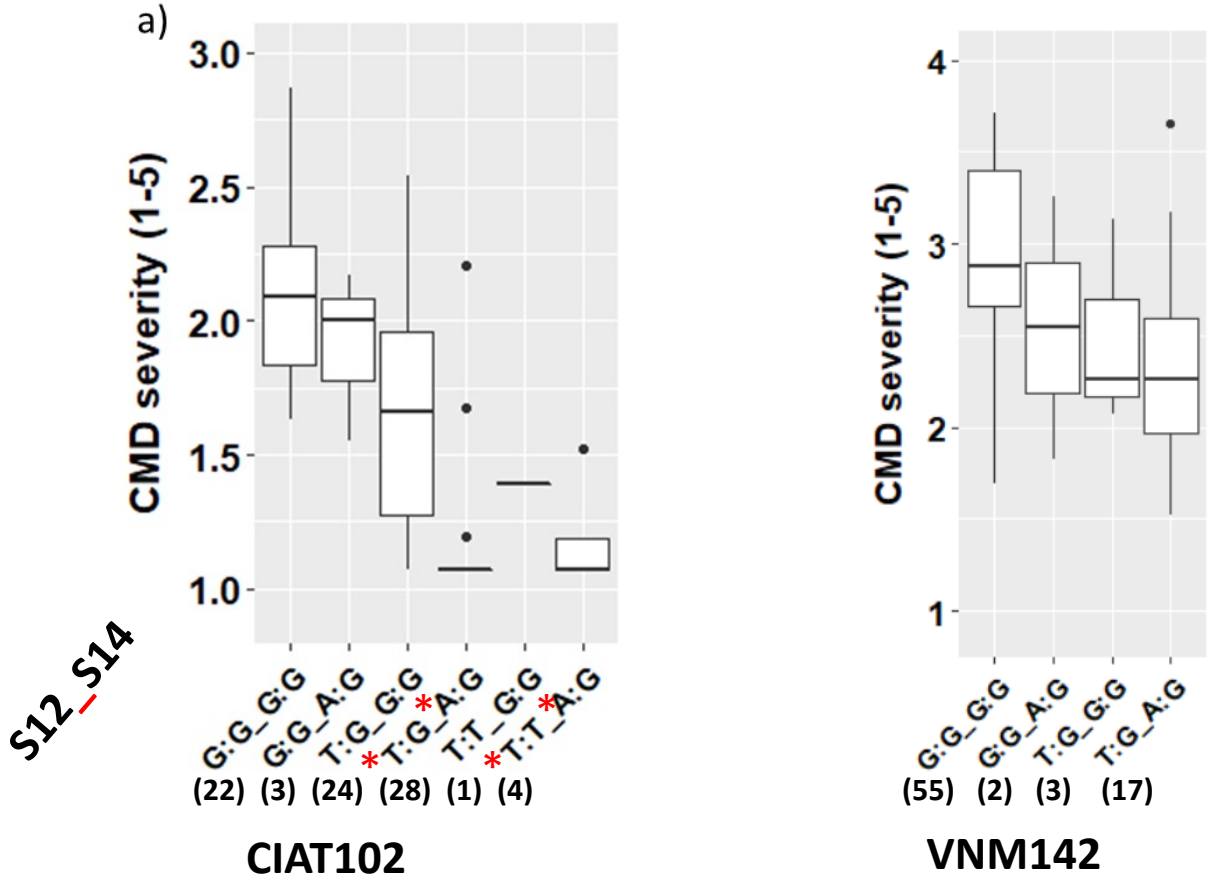


Variation of CMD severity in VNM142 and CIAT102 populations

Population	Trial	Trait	Mean	Median	Rang	V_g	V_e	H^2
VNM142	201801MDEAR	CMD_1.5MAP	1.56	1.43	1.00-4.00	0.10	0.21	0.50
		CMD_3MAP	1.87	1.75	1.00-4.00	0.18	0.22	0.63
		CMD_6MAP	2.23	2.20	1.00-4.00	0.27	0.19	0.75
		CMD_10MAP	2.82	2.86	1.19-4.00	0.40	0.19	0.82
	201901MDEAR*	CMD_10MAP	2.65	2.33	1.00-4.12	1.30	0.04	0.99
	201902MDEAR#	CMD_10MAP	2.83	2.63	1.70-4.10	0.62	0.11	0.94
CIAT102	201903MDEAR	CMD_3MAP	1.73	1.64	1.00-3.77	0.42	0.12	0.91

V_g, total genetic variance among unique clones; V_e, the variance of residue. The calculation of genetic variance was performed by using the mixed models by fitting replications and clones as random effects.
*the trials with 3 clones from VNM142 and four checks, HLS11, KM419, KU50 and C33. MDEAR, cassava mosaic disease advanced yield trial.
#the trials with 9 clones from VNM142 and three checks, HLS11, KM419 and KU50.

CMD2 Markers Works in Segregation Populations



S12_7926132 and S14_4626854

For marker S12, ***T** is the resistant allele; For marker S14, ***A** is the resistant allele

S12_7926132 and S14_4626854 worked well for **segregation populat**ions (e.g., CIAT102), but not for **diversity populations** (e.g., VNM142)

New CMD Resistance to SLCMV Identified from VNM142

Genotype/group	Clone	2018-2019	2019-2020	S12_7926132	S14_4626854
UNK-CI-2	VN19-442	1.5	2.3	T:G	A:G
CR63_PER262_TAI9	VN19-1432, VN19-1556	1.6	1.9	T:G	A:G
KM57_VNM8_Xanh Vinh Phu	VN19-1039, VN19-1050	1.6	1.9	T:G	A:G
UNQ-115	VN19-773	1.7	2.1	T:G	A:G
UNK-F	VN19-1184, VN19-1194	2.0	2.6	T:G	A:G
UNQ-44	VN19-320	1.7	1.8	G:G	G:G
UNK-AF-2	VN19-1805	1.8	NA	G:G	A:G
UNK-CH	VN19-390	1.9	2.2	G:G	G:G
KU50_KM94_TAI16	11 clone samples (e.g., VN19-1739	2.6	3.5	G:G	G:G
KM140	4 clone samples (e.g., VN19-2659)	3.6	NA	G:G	G:G
KM419	2 clone samples (e.g., VN19-2202)	3.0	4.0	G:G	G:G
C33	C33	NA	1.1	T:G	A:G

BLUP of the CMD score at 10 month after planting was provided here for each unique clone (or group)

Continuous Improvement – Future Direction

Genetic Diversity

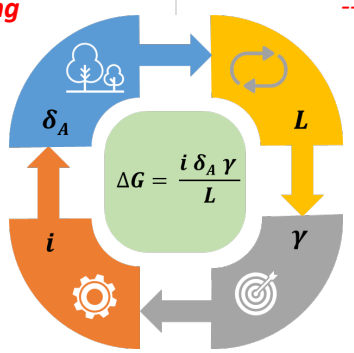
- Variation profiling (2022-)
- **Hybrid Breeding (2019-)**

-- Selfing

Duration of Selection Cycle

- Early flowering (2016-)
- **Genomic Selection (2019-)**

-- Mate and parent selection



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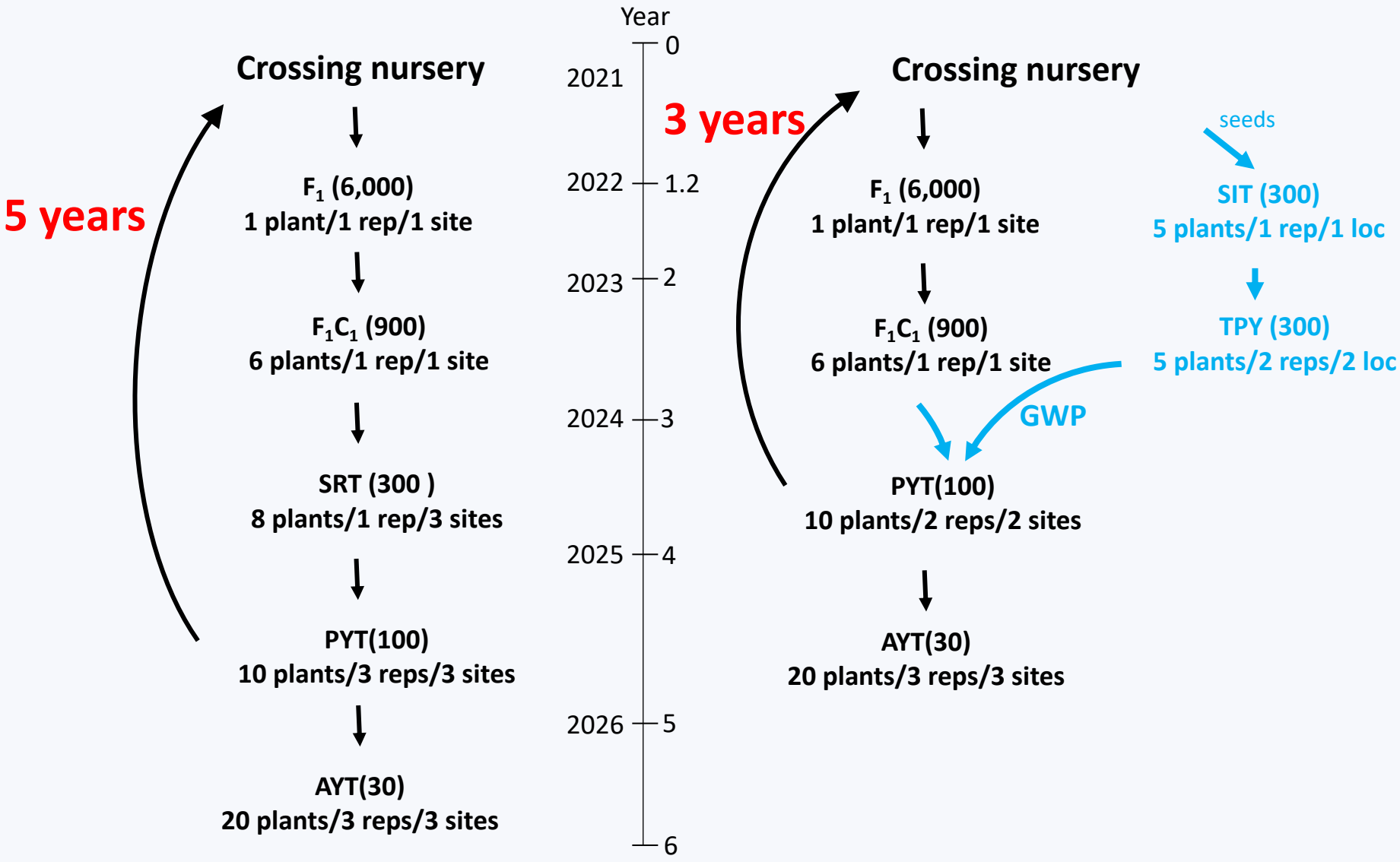
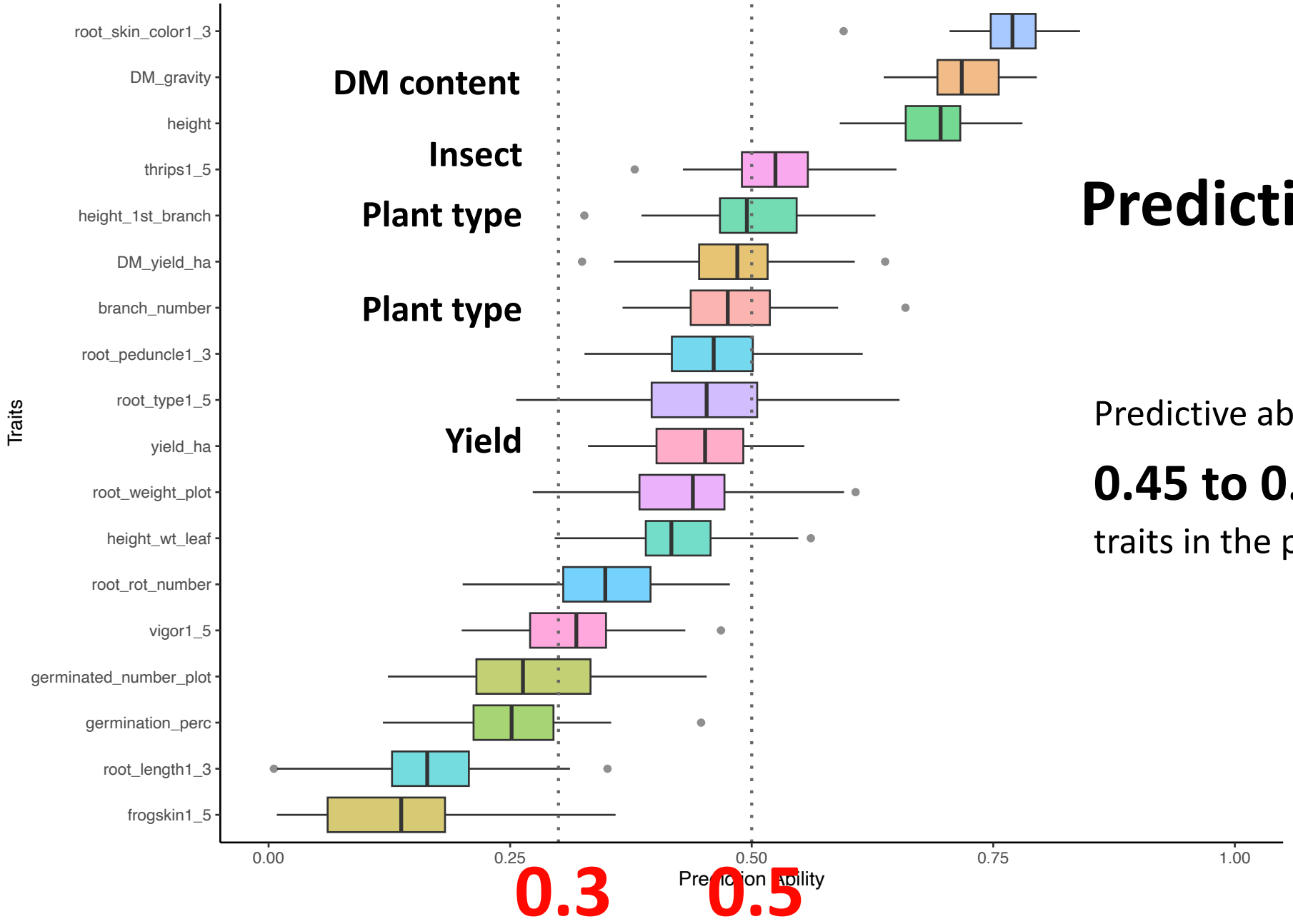
*-- **CMD**, CBSD, DM, **carotenoid**, HCN, WAB, sprouting, ID, flowering, mites, thrips, small granule, plant type*

Cassava Breeding Scheme



Alliance
Bioversity & CIAT



Predictive Ability

Predictive ability ranged from

0.45 to 0.70 for all the traits in the product profile

Alliance Bioversity & CIAT

Cassava Hybrid Breeding

Cassava vs. Maize

Starch

Diploid

Cross-pollinated

Self-compatible

Inbreeding depression

Clonal propagation
– no seed production system

Transform Cassava Breeding using **Inbred Progenitors**

BC, Beta-carotene; CQ, cooking quality; WX, waxy starch; SG, small granule starch; PQ, processing quality

BC, Beta-carotene; CQ, cooking quality; WX, waxy starch; SG, small granule starch; PQ, processing quality

Selective breeding towards **Breeding by design**

Cassava Hybrid Breeding

Alliance Bioversity & CIAT

Understand **inbreeding depression**

Develop semi-**inbred progenitors**

Improve **population** using rapid cycling

Create **heterotic groups**

COLLEGE OF AGRICULTURE & LIFE SCIENCES
Arizona Genomics Institute

PACBIO CERTIFIED SERVICE PROVIDER

华大生命科学研究院 BGI·Research

Short-read **sequencing** & Bioinformatics

CGIAR Excellence in Breeding Platform

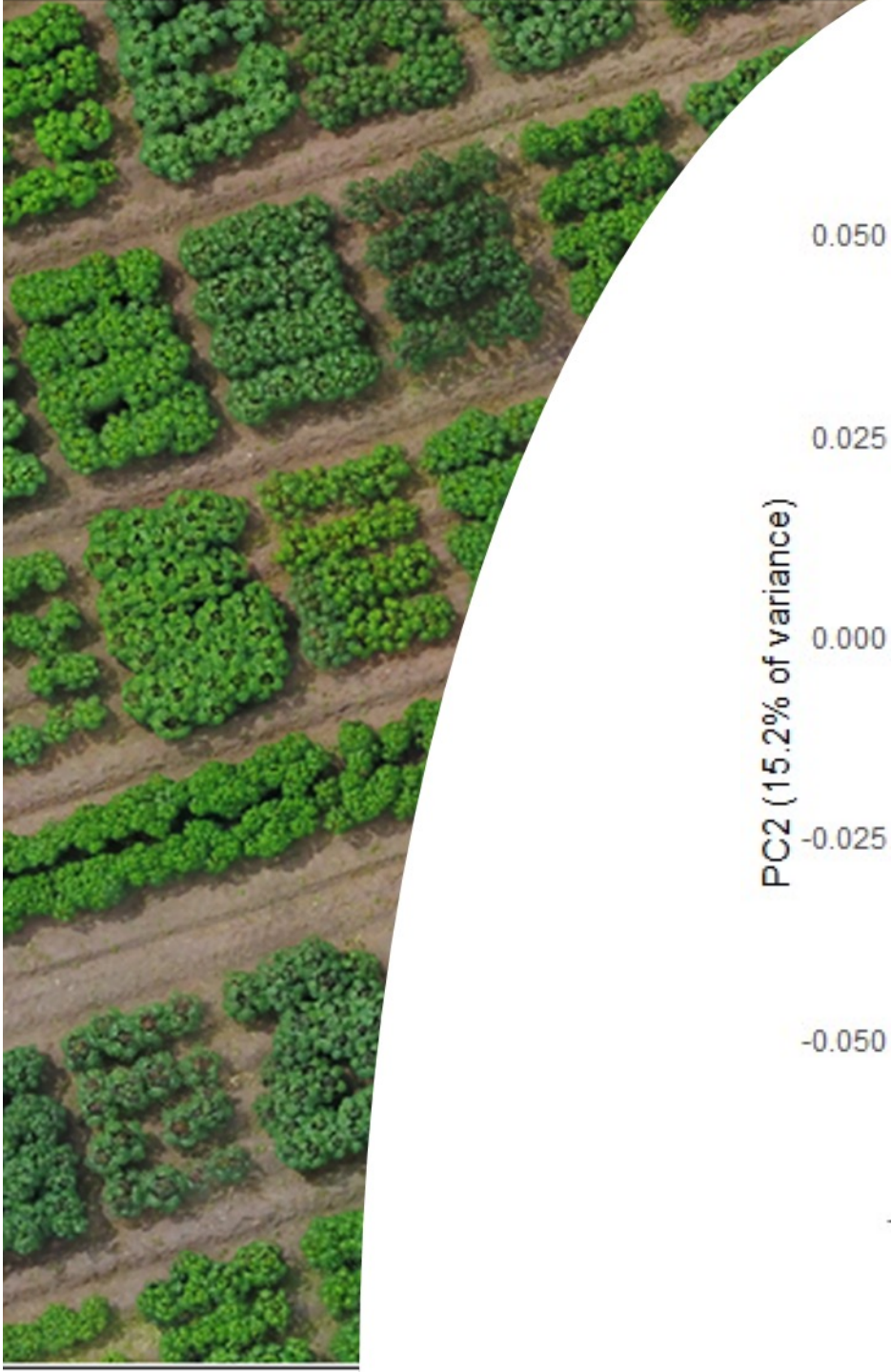
Consulting + QG simulation

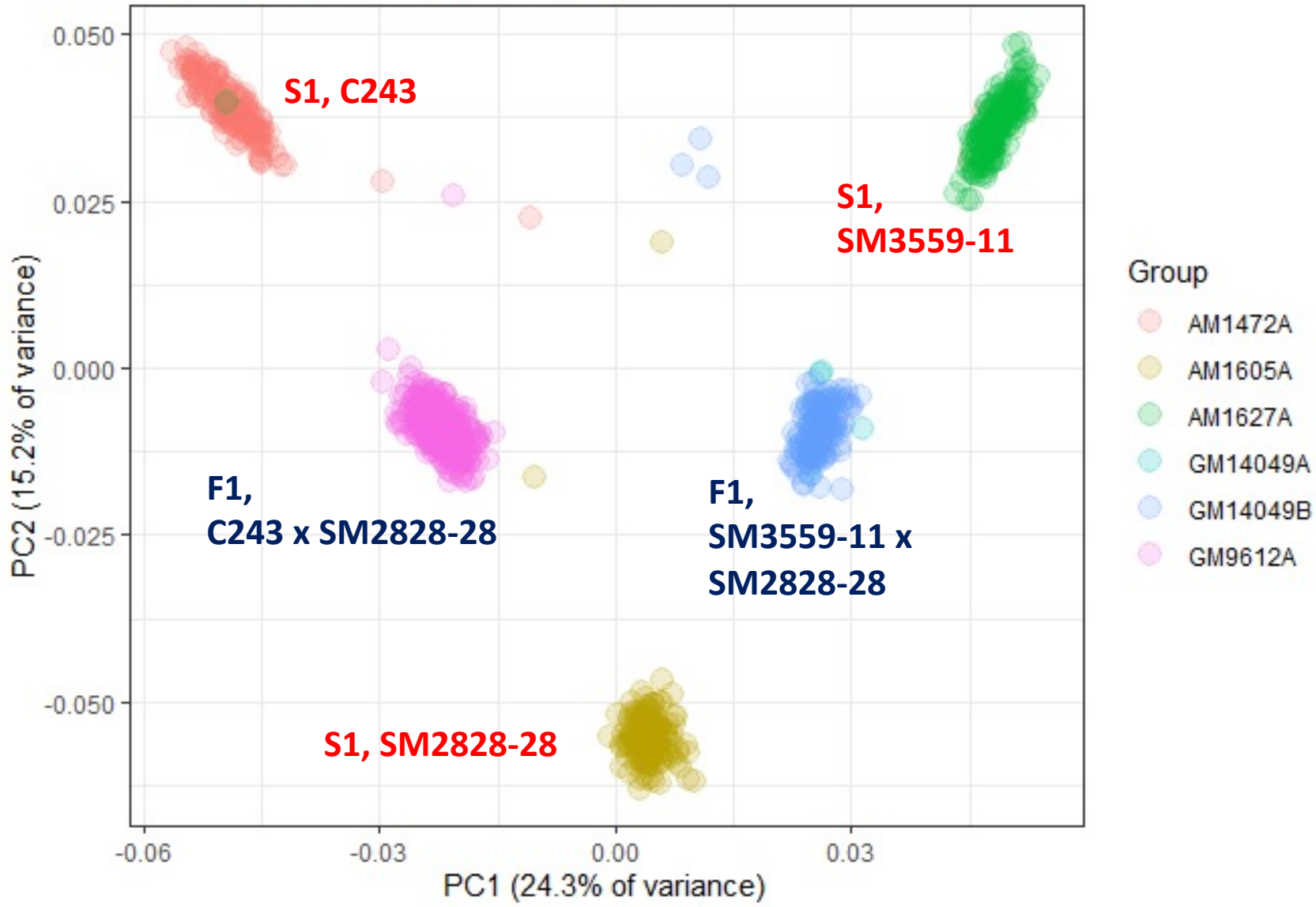
ScreenSYS Screening Cells – Improve Plants

Doubled Haploid technology

GEMS Informatics

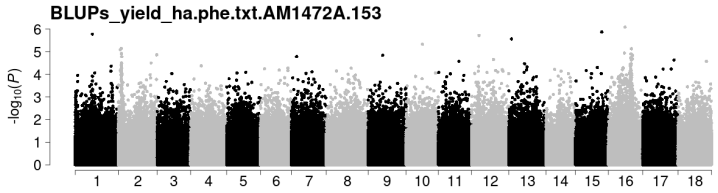
Deleterious Mutations & Database for variation profiling

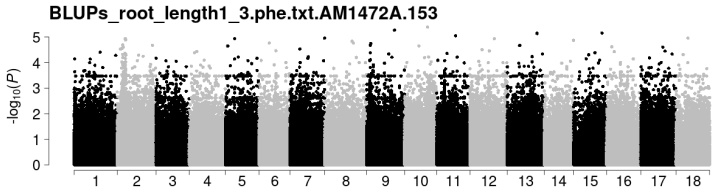


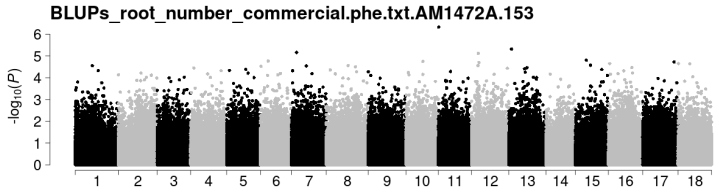

S1, C243
S1,
SM3559-11
F1,
C243 x SM2828-28
F1,
SM3559-11 x
SM2828-28
S1, SM2828-28
0.050
0.025
0.000
-0.025
-0.050
PC2 (15.2% of variance)
-0.06
-0.03
0.00
0.03
PC1 (24.3% of variance)
Group
AM1472A
AM1605A
AM1627A
GM14049A
GM14049B
GM9612A

Family-specific Loci on Chr 5 and 15

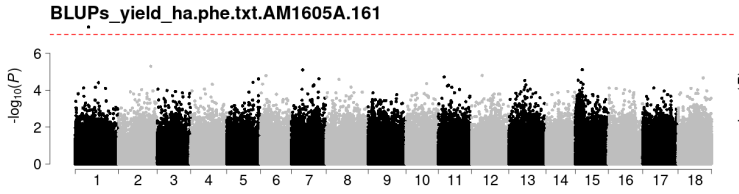
Family 1

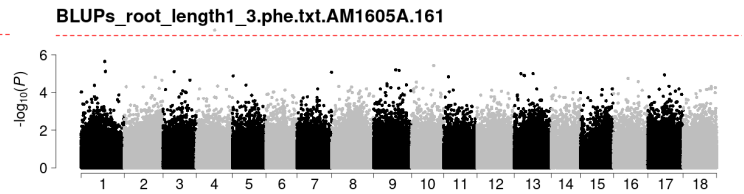


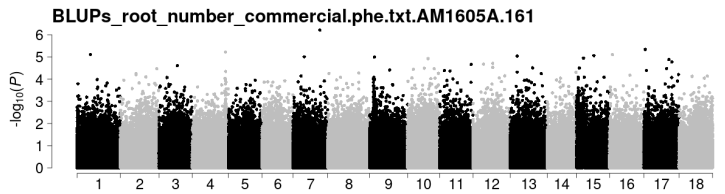




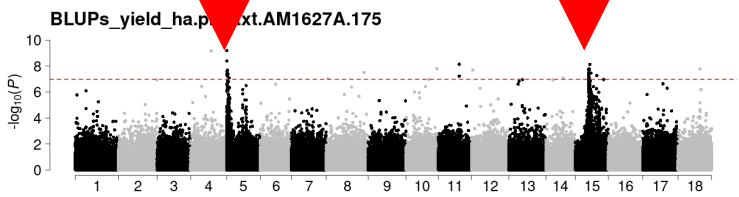
Family 2

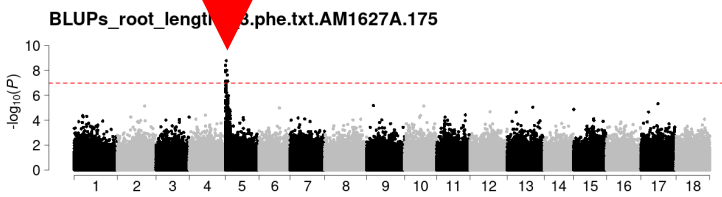


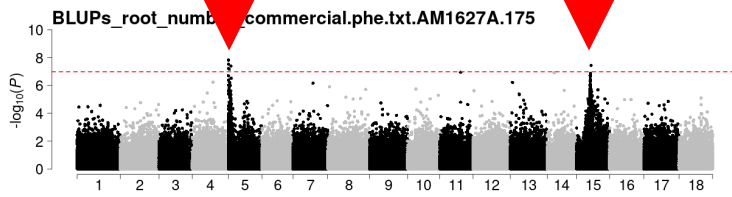




Family 3







Yield **Root Length** **Root Number**

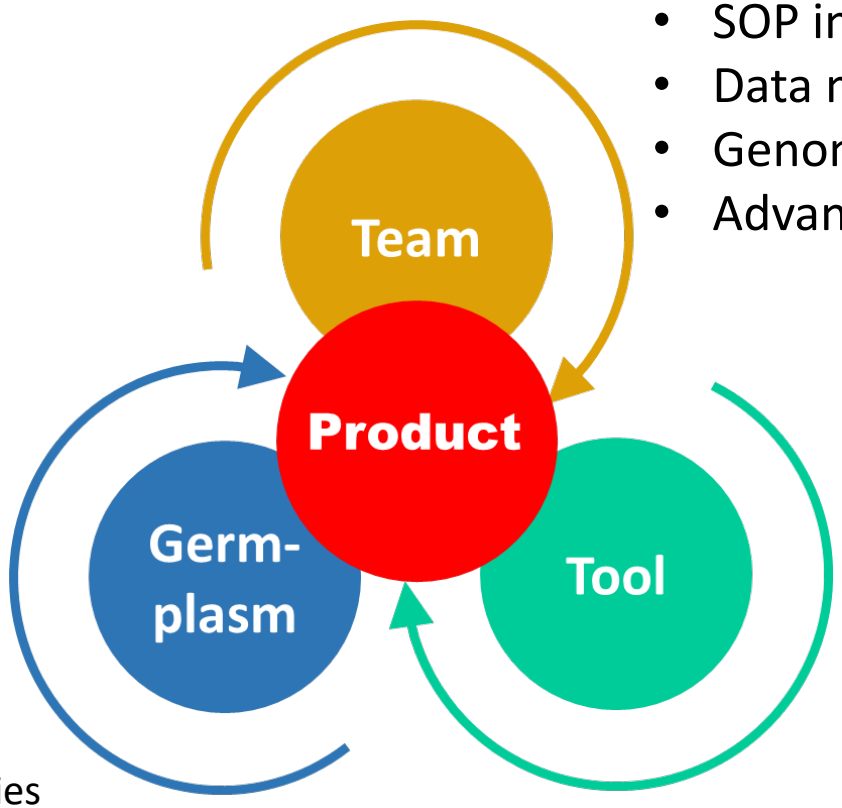
BC, Beta-carotene; CQ, cooking quality; WX, waxy starch; SG, small granule starch; PQ, processing quality

Breeding by design

Future Development in South East Asia

Capacity Building

- Flower inducing technology
- SOP in evaluation
- Data management and analysis
- Genomics-assisted breeding
- Advancement decision making



Disease Resistance

- Resistance to cassava witches' broom
- CBSD resistance
- Root rot tolerance

*core collections and local varieties

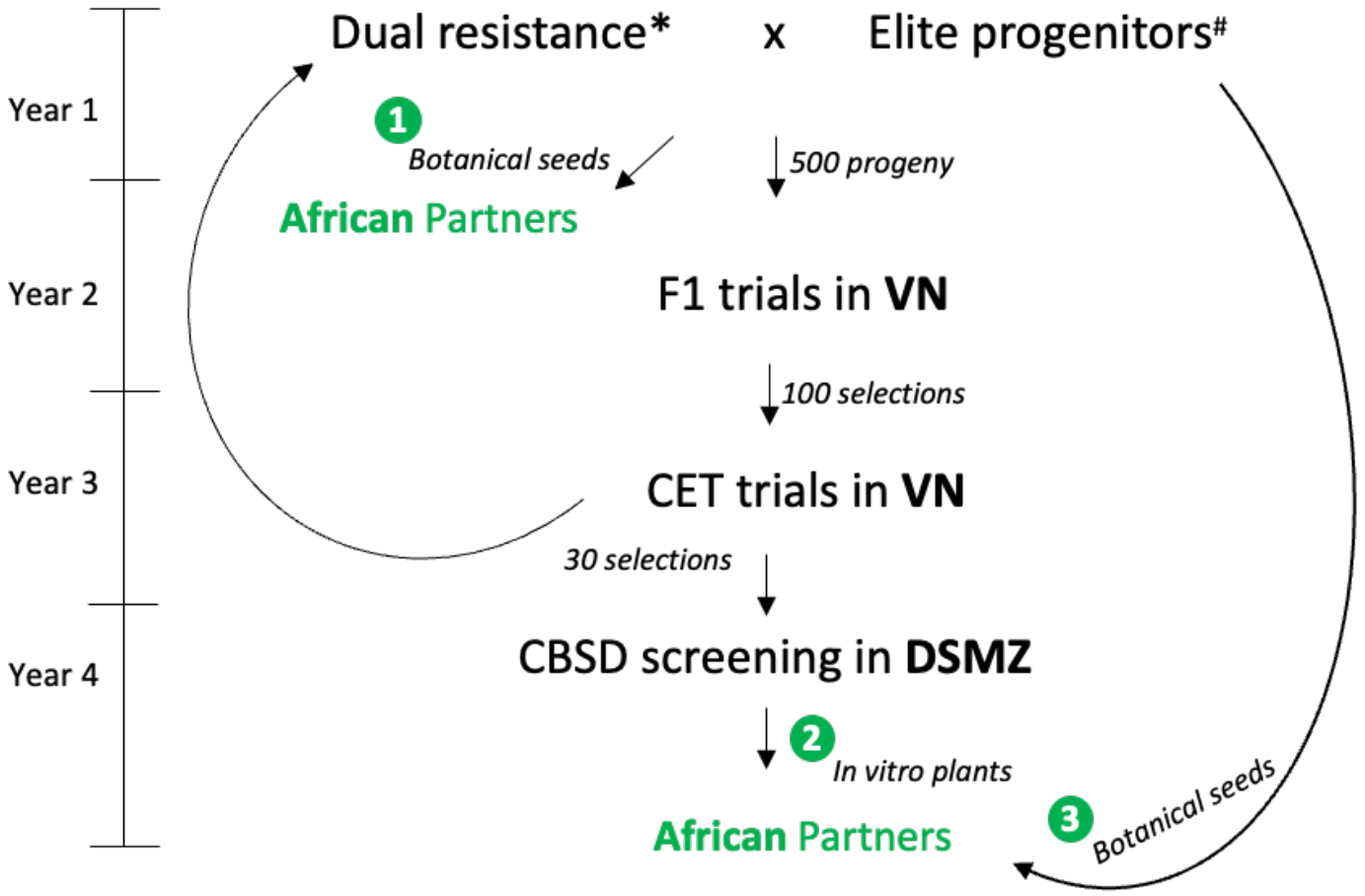
Continuous Improvement

- Genomic selection
- MAS
- Hybrid breeding

Dual Resistant clones to CMD and CBSD from Dr. Winter

standard name	female parent	male parent	
POP112-1	COL40	C33	CBSD & CMD resistance; seeds from CIAT
POP101-1	PER353	GM7673-3	CBSD & CMD resistance; seeds from CIAT
POP108-1	C33	PER353	CBSD & CMD resistance; seeds from CIAT
POP108-10	C33	PER353	CBSD & CMD resistance; seeds from CIAT
POP118-8	COL144	C39	CBSD & CMD resistance; seeds from CIAT

CBSD Breeding in Asia to Serve Africa



** Dual resistance: resistant to both CBSD and CMD;*
VN, Vietnam; DSMZ, Leibniz Institute DSMZ-German
 # progenitors with erect plant type, high and stable dry matter and high yield


NIKE
FOX