



I N T E R N A T I O N A L P O T A T O C E N T E R

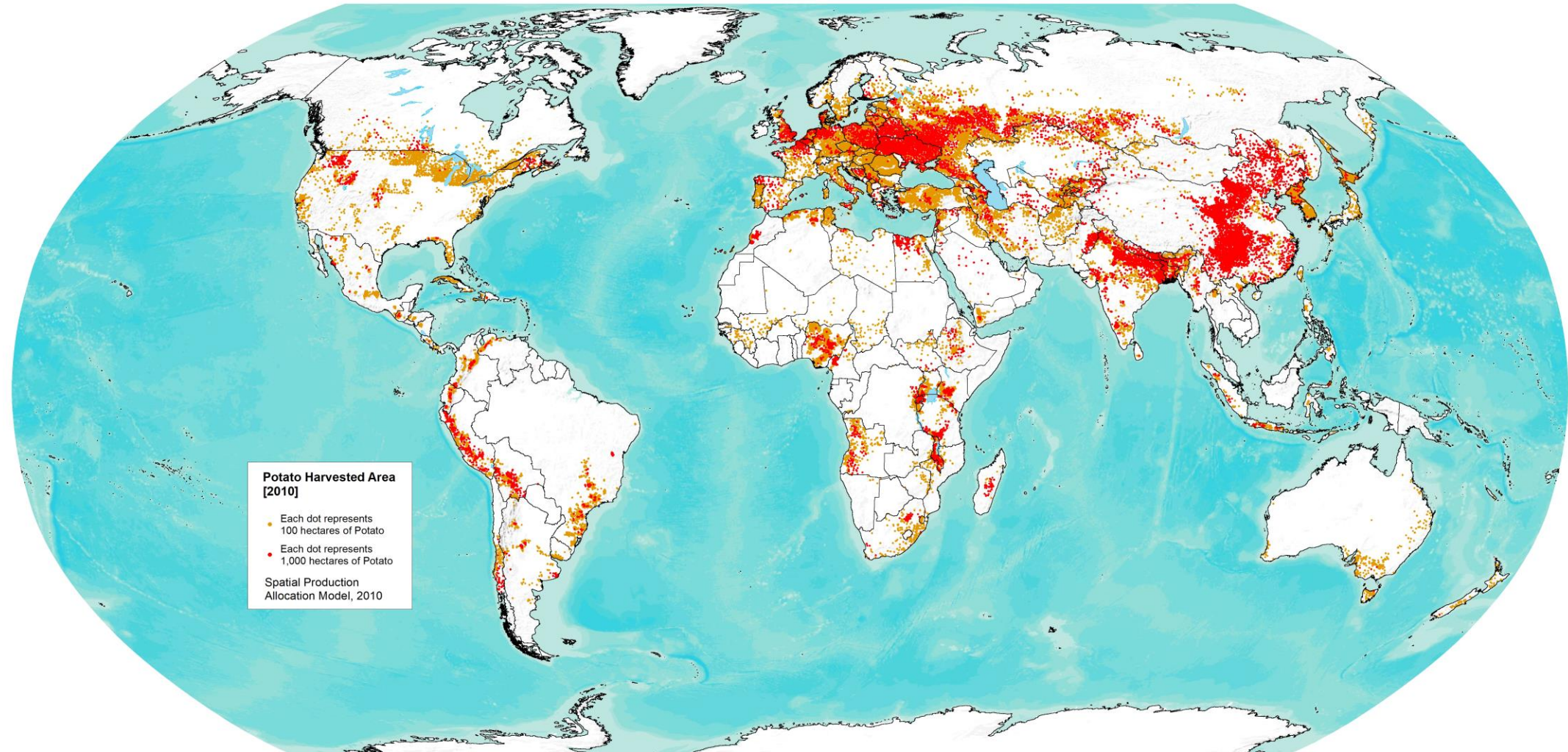
## Potato Breeding: Overview of the operations in Africa

Thiago Mendes  
Africa Breeding Team



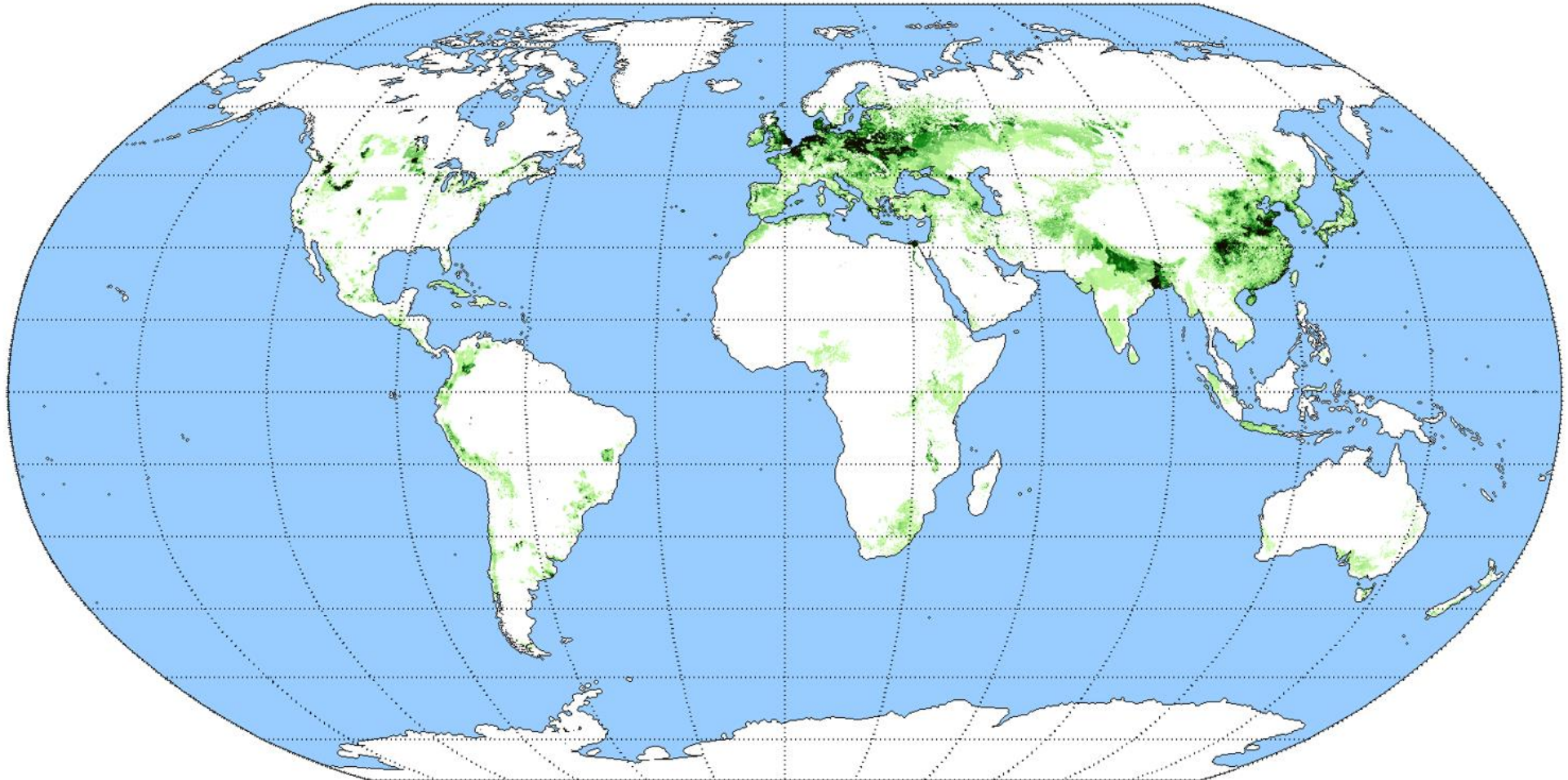
# General Introduction

## POTATO HARVESTED AREA



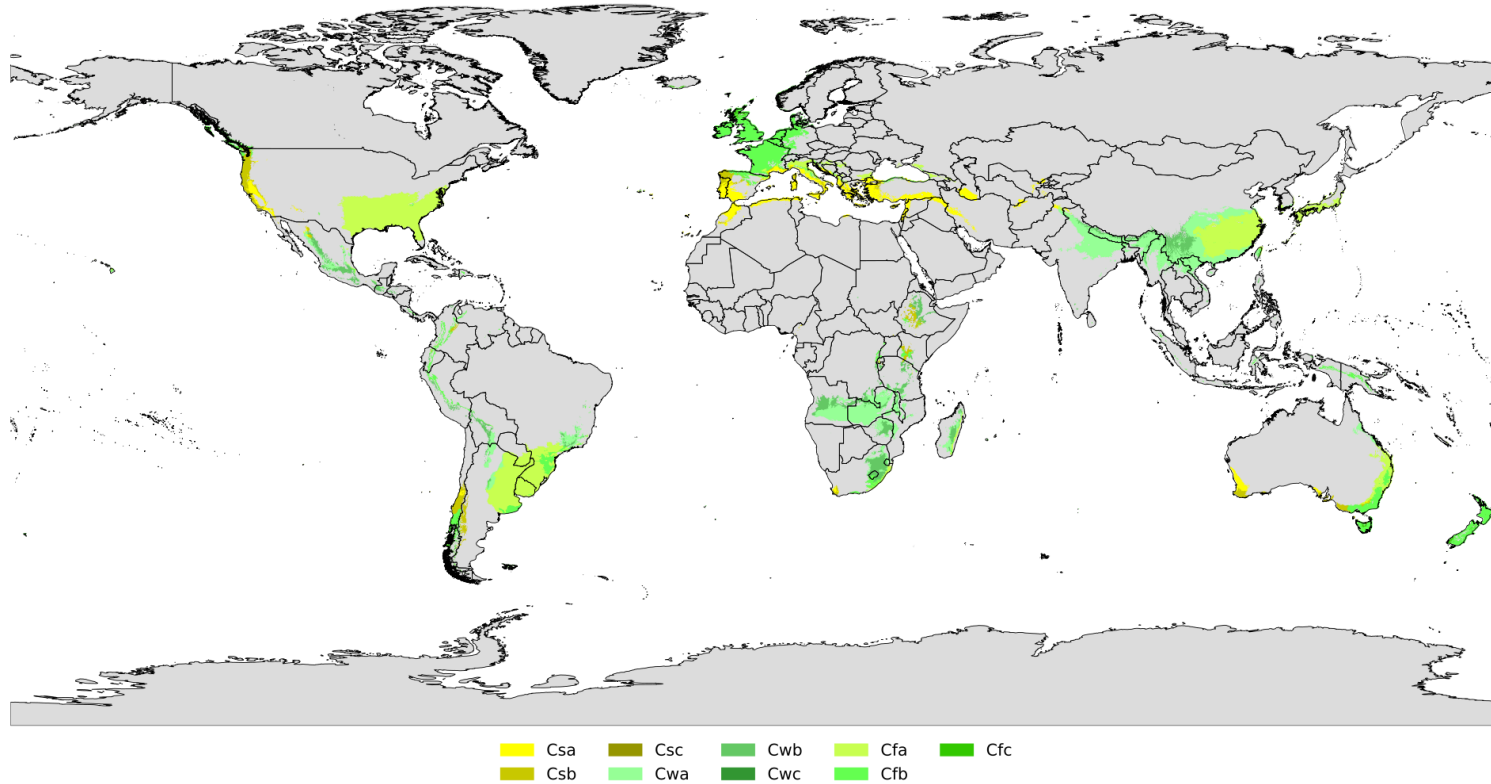
# General Introduction

## POTATO GLOBAL YIELD



# General Introduction

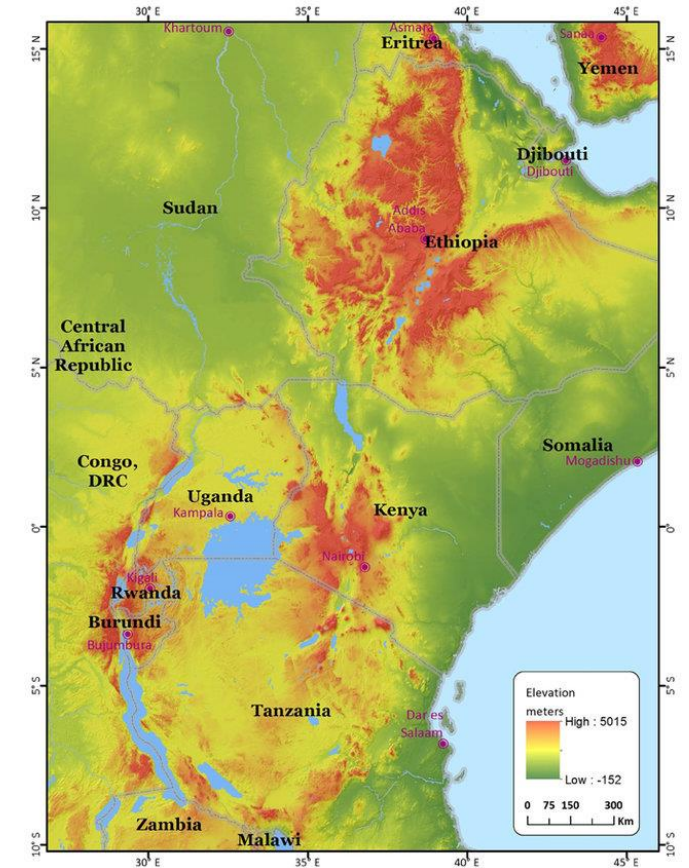
## TARGET ENVIROMENTS



Source: Beck et al.: Present and future Köppen-Geiger climate classification maps at 1-km resolution, Scientific Data 5:180214, doi:10.1038/sdata.2018.214 (2018)

### Subtropical highland climate (Cfb, Cwb, Cwc)

This type of climate exists in parts of east, south and southeastern [Africa](#), interior southern Africa and elevated portions of eastern Africa as far north as [Ethiopia](#) and of western Africa (west region of Cameroon) up to the southwestern [Angola](#) highlands also share this climate type

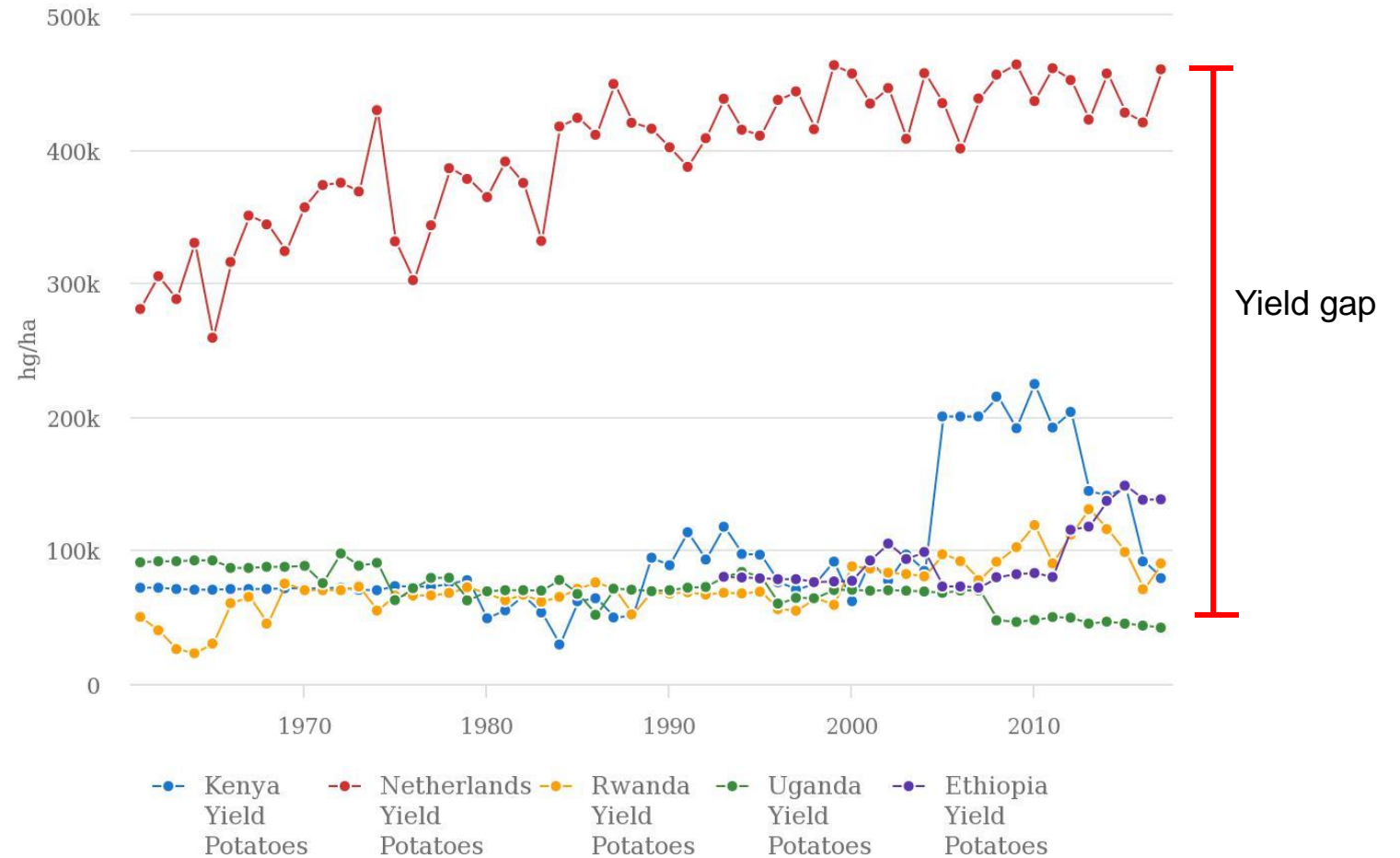


### East Africa Highlands

# General Introduction

## EAST AFRICA POTATO YIELD

Countries	Area harvested	Yield
Ethiopia	68,732*	14
Kenya	175,050	10
Rwanda	95,766	9
Tanzania	136,251	8
Uganda	40,670	4
-----		
	516,468	9
-----		
Netherlands	160,475	42



Source: FAOSTAT (Mar 08, 2019)

# Breeding objectives and product profile

## BRIEF

- Market segment
  - processing (starch, chips, French fries)
  - table (firm cooking, mashed, or homemade fries)
- Yield, biotic and abiotic tolerances
- Taste, skin, colour, and appeal
- Adapted to mechanical harvesting
- Storability

Search for potato East-Africa in  
<https://glomip.cgiar.org/target-product-profiles>

# Breeding objectives and product profile

## PRODUCT PROFILE

<b>Country</b>	Rwanda	Uganda	Ethiopia	Kenya
<b>Continent</b>	Africa	Africa	Africa	Africa
<b>Institution</b>	RAB-CIP	NARO-CIP	EIAR-CIP	KALRO-CIP
<b>Name of commercial product to be replaced/ OR Companion Crop For the Market</b>	Kinigi	NAROPOT4	Gudene	Shangi
<b>Skin colour</b>	Cream	Red	Cream	White
<b>Market-segment</b>	Table	Table	Table	Table
<b>Agro-ecology zone</b>	Higlands	Higlands	Higlands	Higlands
<b>Basic trait 1</b>	Tate	Taste	Storability	Short-Dormancy
<b>Basic trait 2</b>	Red-skin	Earliness	Taste	Multi-purpose
<b>Basic trait 3</b>	Storability	Short-dormance	Tuber-apearence	Cooking-time
<b>Basic trait 4</b>	Earliness	Late-blight	Resistance-bruising	Earliness
<b>Basic trait 5</b>				Creamy-flesh
<b>Value-added trait 1</b>	Dry-matter	Storability	Late-blight	Late-blight
<b>Benchmark line or variety</b>	Kinigi	Rutuku	Gudene	Sherekea
<b>Your trait compare to the benchmark percentage</b>	Greater 2%	equal	greater 20%	equal
<b>Value-added trait 2</b>	Late-blight	Tuber-size	Dry-matter	Storability
<b>Benchmark line or variety</b>	Kinigi	Kinigi	Belete	Shangi
<b>Your trait compare to the benchmark percentage</b>	greater 50%	equal	equal	greater 30 days
<b>Value-added trait 3</b>	Dormancy			Shallow-eye
<b>Benchmark line or variety</b>	Kinigi			Desiree
<b>Your trait compare to the benchmark percentage</b>	Less 3 weeks			equal

<b>Rwanda</b>	<b>Uganda</b>	<b>Ethiopia</b>	<b>Kenya</b>
<b>Basic trait</b>			
Taste	Taste	Storability	Short-Dormancy
Red-skin	Earliness	Taste	Multi-purpose
Storability	Short-dormancy	Tuber-apearence	Cooking-time
Earliness	Late-blight	Resistance-bruising	Earliness
<b>Value-added trait</b>			
Dry-matter	Storability	Late-blight	Late-blight
Late-blight	Tuber-size	Dry-matter	Storability
Short-dormancy			Shallow-eye



<https://excellenceinbreeding.org/toolbox/tools/product-replacement-strategy-guide>

# Breeding objectives and product profile

## MARKET SEGMENT ANALYSIS

<i>Country</i>	Rwanda	Uganda	Ethiopia	Kenya
<i>Institution</i>	RAB-CIP	NARO-CIP	EIAR-CIP	KALRO-CIP
<i>To be replaced</i>	Kinigi	NAROPOT4	Gudene	Shangi
<i>Released</i>	1983	2000	2006	2015
<i>Market share (%)</i>	40	50	30	70
<i>Market-segment</i>	Multipurpose	Multipurpose	Multipurpose	Multipurpose
<i>Sector</i>	Retail fresh	Retail fresh	Retail fresh	Retail fresh
<i>Area harvested k ha FAO (GD)</i>	106	38 (112)	66	146
<i>Agro-ecology zone</i>	Highland	Mid-highland	Mid-highland	Highland

# Breeding objectives, product profile

## MARKET SEGMENT ANALYSIS

ONE CGIAR Sub Region	East Africa
Market Segment Description:	Fast cooking early maturing <u>table potato</u> with short dormancy
Market segment(s) targeted	African tropical highlands <u>table potato</u>
Agro-Ecological Zone(s) in the market segment:	African highlands
Countries targeted	Kenya (200K ha), Rwanda (104K), Ethiopia (72K), Uganda (36K), Tanzania* (137k)
Pipeline name and description	East- African dual-purpose potato for tropical highlands with late blight resistance
Total Ha targeted by pipeline	412,000
Spillover countries	Malawi, Burundi, DCR Congo, Zambia, Mozambique, Angola, Madagascar, Cameron, Nigeria, Zimbabwe
Pipeline Investment	\$ 1,212,760.82
Hectares targeted (ha)	412,000.00
Average Yield/Hectare (kg/ha)	8,000
Current Average Selling price	60KSh/Kg 1 KSH = \$0.0092US 0.55US/kg
Average selling price US\$/kg	0.55
Value of the market segment \$USMM	1812.8

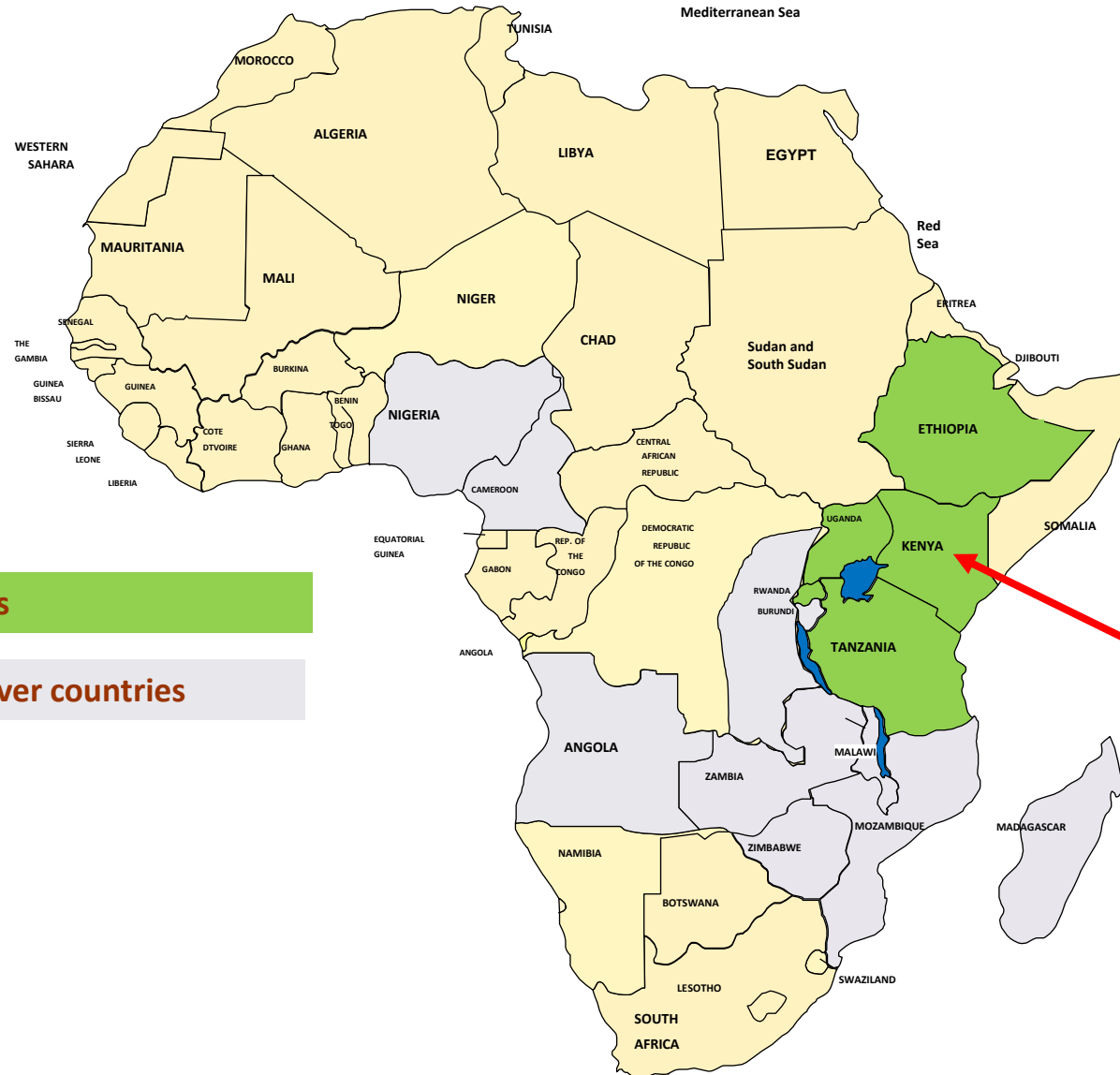
# Breeding objectives, product profile

## MARKET INFO – KENYA

Kenya	2020	2030	2040	2050
Population in Mio	53	66	79	91
Potato consumption per capita (in kg)	25	26	27	28
Consumption in 1000 Tons	1325	1716	2133	2548
Fresh segment in %	81	80	79	78
Processing segment in %	19	20	21	22
Importation in 1000 Tons – Fresh segment				
Importation in 1000 Tons – Processing segment	55	60	65	70
Production in 1000 Tons – Fresh segment	1400	1800	2250	2700
Yield in T/Ha	10	12	14	16
Acreage in 1000 Ha	140	151	160	168
Volume Seeds Potato in 1000 Tons assuming 15% refreshment	42	45	48	50
Value Seeds Potato in USD Million	25	27	28	30

# Breeding and testing strategies

## CIP POTATO BREEDING PROGRAM



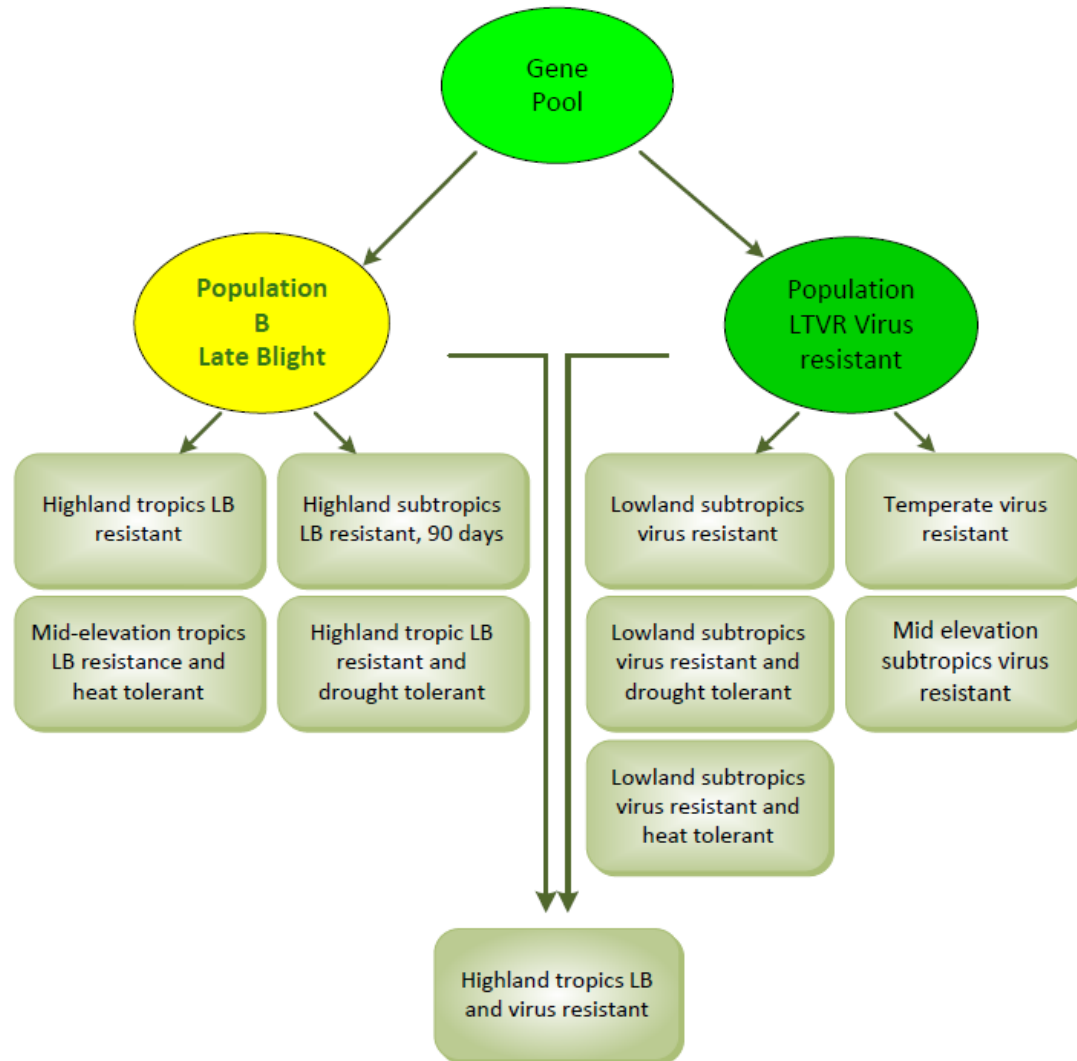
Target countries

Potential spill over countries

Potato Breeder (1)  
Technicians (4)  
Crossing/Selection/  
Evaluation/Distribution hub

# CIP's Potato Breeding Program

*Advanced Population with specific adaptation to the most important agro-ecologies of the tropics*



**Figure 3.** Advanced populations with specific adaptation to the most important agro-ecologies of the tropics.

**Tropical highlands**  
B1 - *andigena* source of LB resistance  
LBHT – B3 related  
Fe & Zn biofortified – 2X

**Subtropical lowlands**  
Fe & Zn biofortified – 4X

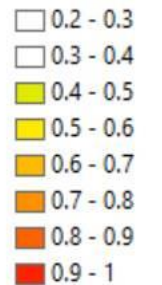
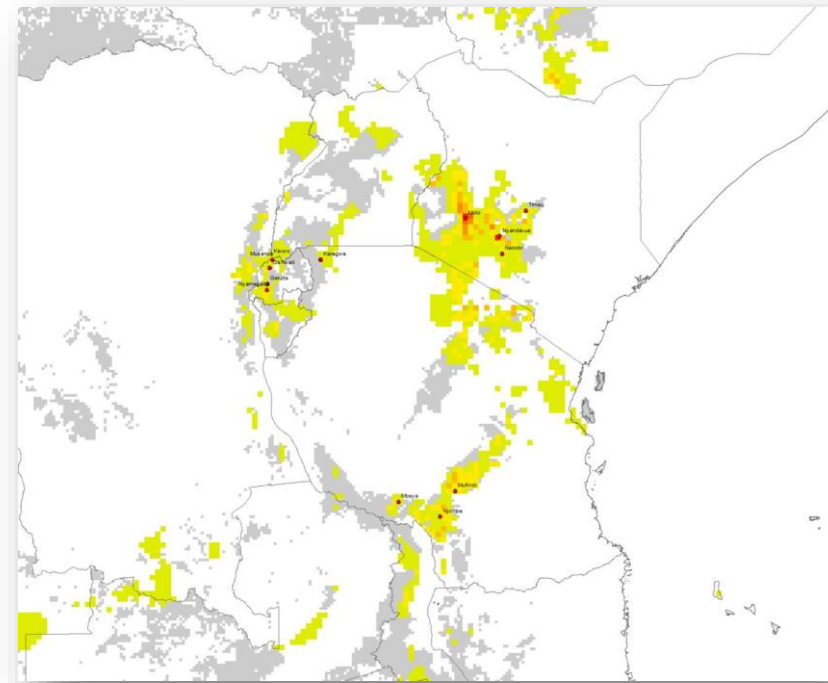
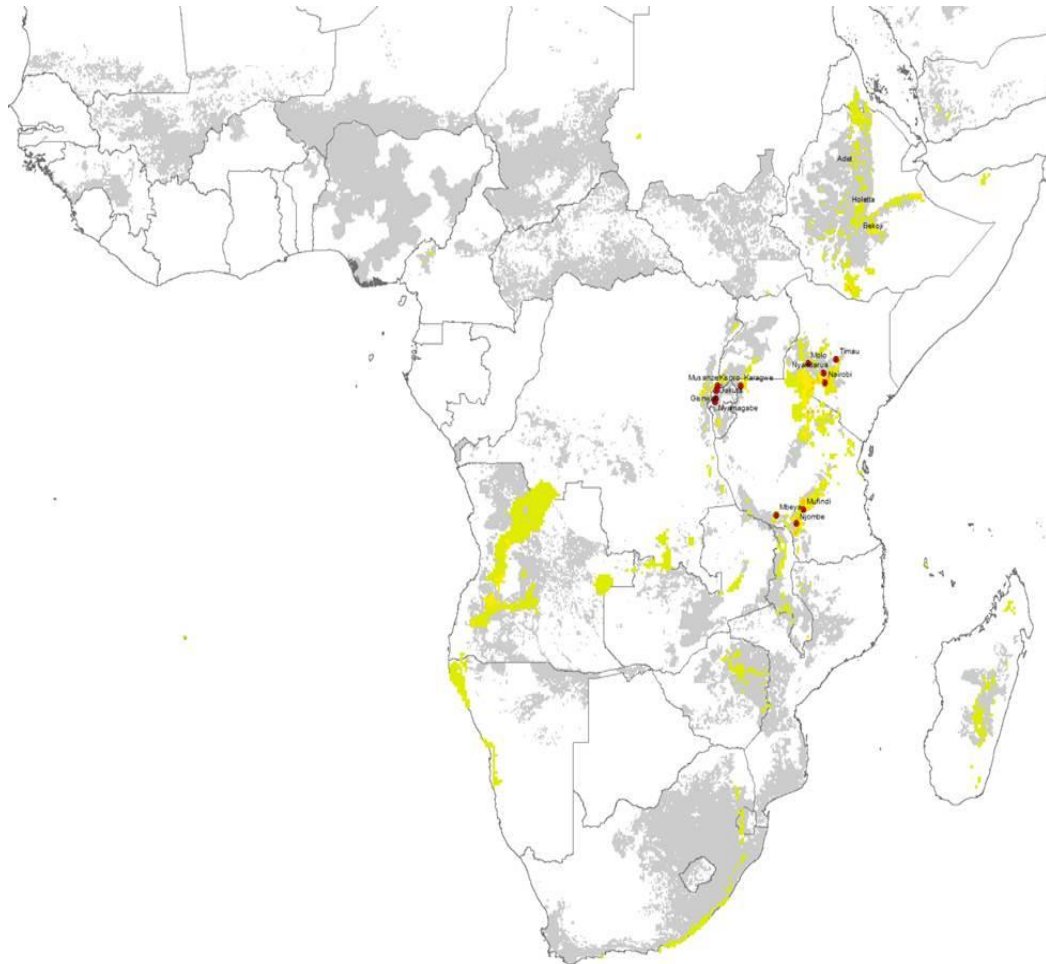
# Breeding and testing strategies

## TARGET ENVIROMENTS (potato seasons)

Country	Season		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ethiopia	1	Belg		█										
Ethiopia	2	Meher							█					
Ethiopia	3	Off season										█		
Kenya	1	Long rain			█									
Kenya	2	Short rain									█			
Rwanda	1	Main			█									
Rwanda	2											█		
Tanzania	1	Main		█										
Tanzania	2								█					
Tanzania	3										█			
Uganda	1	Short rain		█										
Uganda	2	Off season					█							
Uganda	3	Long rain								█				

# Breeding and testing strategies

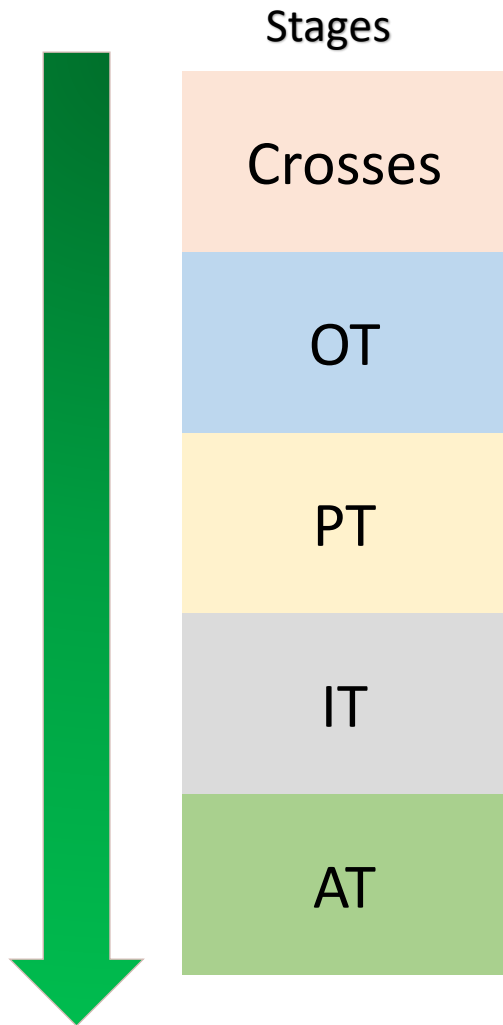
Breeding TARGET ENVIRONMENTS – Similarity



Climate similarity. Gray areas are the distribution of potato cultivation.

# Breeding and testing strategies

## OVERVIEW



Recycling parents

Year	Stages	N genotypes	Locations	Selection intensities (%)	Statistic design
0	Crossing block (CO)	20	1		Crossing block (Mating designs: Line x tester, North Carolina Design I, II, recombination)
1	Observation Trial (OT)	5000	1	0-10	Singles Hills
2	Preliminary trial (PT)	500	1	30-40	Observation plots - five plants (Argument row-col)
3	Intermediate trial (IT)	50-200	3	20-30	Resolvable Row-Column/ four replications/ten plants per plot.
4	Advanced trial (AT)	20	4	10-20	Resolvable Row-Column/ four replications/ten plants.

Released variety

# Breeding and testing strategies OVERVIEW

Year 1	Season 1	Parents in Crossing Program	20					
Year 2	Season 1	Breeding Crosses	57					
Year 2	Season 2	FAMILIES	25	X	CLONES per family	200	=	5000
		Selection Traits	Selection		Testing			
		Selection Made: YES Traits: Plant appearance and vigor, skin and flesh color, tuber shape, appearance and uniformity tuber Selection intensity: 0-10%			EET (Early Evaluation Trials) Exp Design: Row/Column # of years: 1 # of locations: 1 # of entries: 5004 # of reps: 1 # of checks: 4			
Year 3	Season 1	CLONES	500	X		0	=	500
		Selection Made: YES Traits: Resistance to late blight in foliage and tubers, yield, plant vigor, maturity, dormance, dry matter Selection intensity: 30-40%			PYT (Preliminary Yield Trials) Exp Design: Row/Column # of years: 1 # of locations: 1 # of entries: 504 # of reps: 1 # of checks: 4			
Year 3	Season 2	CLONES	200	X		0	=	200
		Selection Made: YES Traits: Resistance to late blight in foliage and tubers, yield, plant vigor, maturity, dry matter Selection intensity: 20-30%	MAS: YES Traits: Virus and late blight		PYT (Preliminary Yield Trials) Exp Design: Row/Column # of years: 1 # of locations: 2 # of entries: 204 # of reps: 2 # of checks: 4			
Year 4	Season 1	CLONES	50	X		0	=	50
		Selection Made: YES Traits: Resistance to late blight, yield, plant vigor, maturity, dormance, dry matter, processing quality and cooking time. Selection intensity: 10-20%			PYT and On-Farm Testing Exp Design: Row/Column # of years: 1 # of locations: 3 # of entries: 54 # of reps: 4 # of checks: 4			
Year 4	Season 2	CLONES	15	X		0	=	15
		Selection Made: YES Traits: Resistance to late blight, yield, plant vigor, maturity, dormance, dry matter, processing quality and cooking time. Selection intensity:			AYT (Advanced Yield Trials) Exp Design: RCBD # of years: 1 # of locations: 3 # of entries: 14 # of reps: 4 # of checks: 4			Material sent to NARS  Recycled as parents

# Population improvement

## SSA Breeding COHORT

Year*	Cycles						
	1	2	3	4	5	6	...
2021	Crosses						
2022	OT	Crosses					
2023	PT	OT	Crosses				
2024	IT	PT	OT	Crosses			
2025	AT	IT	PT	OT	Crosses		
2026		AT	IT	PT	OT	Crosses	
2027			AT	IT	PT	OT	
2028				AT	IT	PT	
2029					AT	IT	
2030						AT	
...							

30
5000
500
100
10

\* Two seasons per year

# Breeding and testing strategies

## FIELD TRIALS

### ➤ **Augmented row-column design (OT)**

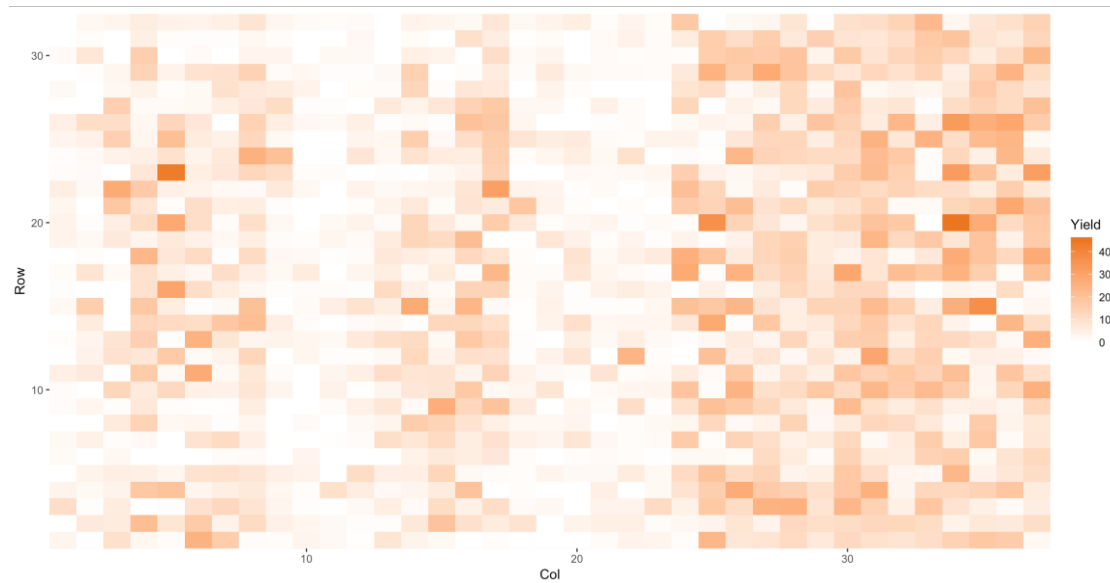
- augmented refers here to the replicated checks
- test genotypes are unreplicated and thus randomized without restrictions
- check genotypes are replicated and randomized using row and column blocks

### ➤ **Resolvable row column design (IT – AT)**

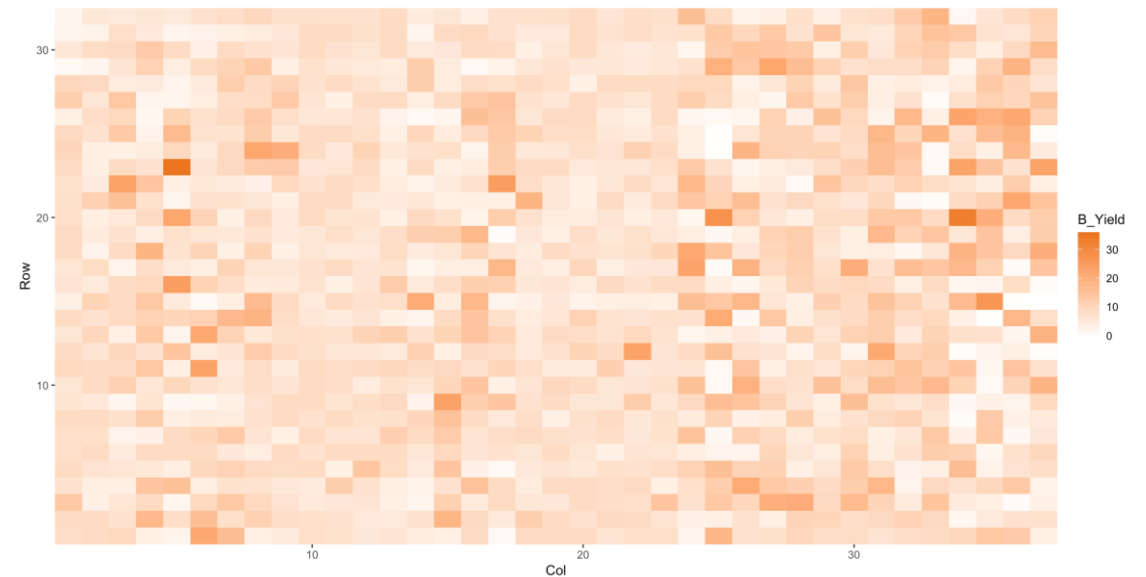
- resolvable means that there are complete blocks (cf. RCBD)
- row-column means that the rows and columns are treated as incomplete blocks (cf. 1-dimensional incomplete blocks of alpha-design)

# Breeding and testing strategies

## FIELD TRIALS



```
spat2<-asreml(fixed=Yield~1,  
             random=~ROWf+COLf+Variety,  
             rcov=~ar1(COLf):ar1(ROWf),data=spatial)  
summary(spat2)$varcomp
```



# Breeding and testing strategies

## LIST OF PARENTS

### 2018

#	Parents	Female	Male
1	CIP304347.006	CIP392820.1	CIP676008
2	CIP312076.782	CIP392820.1	CIP398098.119
3	CIP312279.738	CIP304371.67	CIP398203.244
4	CIP312297.738	CIP304379.110	CIP398208.670
5	CIP312357.769	CIP302476.108	CIP398203.244
6	CIP312463.746	CIP397077.16	CIP398203.244
7	CIP314351.006	CIP304349.25	CIP304372.7
8	CIP314881.008	CIP801088	CIP302498.77
9	CIP394034.065	B79.638.1	CIP676008
10	CIP395193.006	CIP388611.22	C92.030
11	CIP396241.004	CIP392634.52	CIP392626.9
12	CIP397036.007	CIP392011.1	CIP392745.7
13	CIP397197.009	CIP388615.22	CIP388972.22
14	Meru mugaruro	?	?
15	Nyayo	?	?
16	Shangi	?	?
17	CIP398190.615	CIP393077.54	CIP392639.2
18	CIP398208.505	CIP393371.58	CIP392633.64
19	Ex-Shinyanga	?	?
20	Unica	CIP387521.3	APHRODITE

### 2022

#	CIP Clone No	Variety name	Female	Male
1	CIP398208.704	Chulu	CIP393371.58	CIP392633.64
2	CIP393371.157	Wanjiku	CIP387170.16	CIP389746.2
3	CIP392797.22	UNICA	CIP387521.3	APHRODITE
4	CIP393077.159	Konjo	CIP387348.2	CIP389746.2
5	CIP393385.39	Sherekea	CIP387231.7	CIP387170.9
6	CIP393371.58	Kenya mpya	CIP387170.16	CIP389746.2
7	Shangi	Shangi	?	?
8	CIP387121.4*	NAROPOT4	CIP381401.11	CIP575049
9	CIP378699.2	Kinigi	65-ZA-5	YY.1
10	CIP314938.014	Clone	CIP397069.11	CIP398098.119
11	CIP314926.026	Clone	CIP392820.1	CIP398208.219
12	CIP314915.069	Clone	CIP393371.58	Shangi
13	CIP314910.019	Clone	CIP800048	CIP398298.510
14	CIP314909.279	Clone	CIP393385.39	CIP398201.510
15	CIP313011.028	Clone	CIP393385.39	Shangi
16	CIP313001.649	Clone	CIP381381.20	CIP398208.505
17	CIP312084.731	Clone	CIP392797.22	Shangi
18	CIP312010.759	Clone	Nyayo	CIP399001.53
19	Dutch	Europe		
20	Sagitta	Europe		
21	Taurus	Europe		

# Breeding and testing strategies

## FACILITIES



Green house and TC Lab.

# TC lab at KEPHIS



# Breeding and testing strategies

## CIP POTATO BREEDING PROGRAM



University of Nairobi – Kabete Campus  
Field trials and diffuse light storage





Kenya (2021)



Kenya (2021)



Kenya (2019)





Kenya (2021)









International Potato Center  
PLOT: 1 ROW: 1 CIP314926.26  
REP: 1 COL: 1  
SAP13/LTVR

Kenya (2019)



International Potato Center  
PLOT: 15 ROW: 1 CIP312075.712  
REP: 1 COL: 1

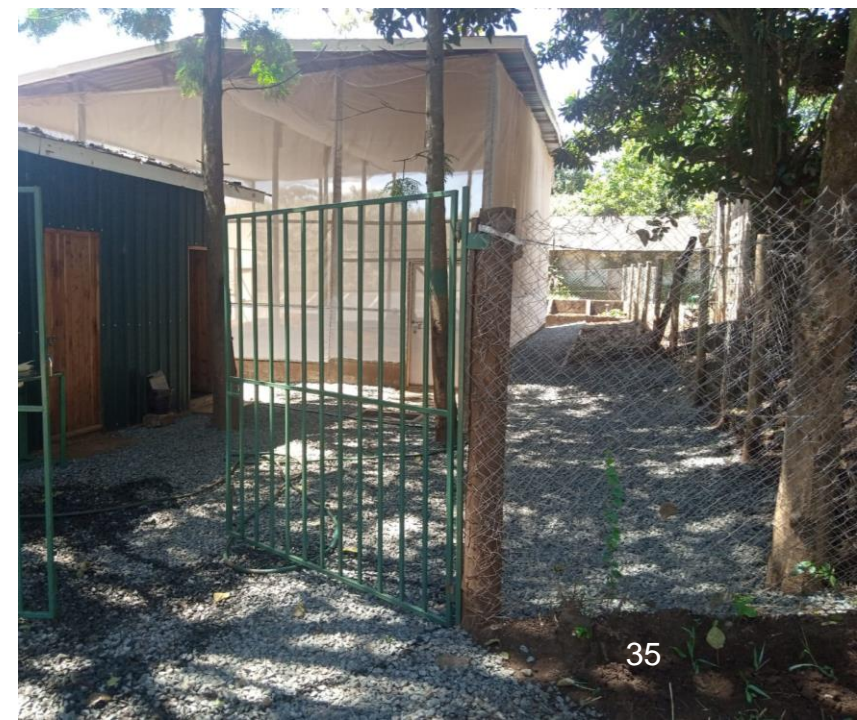


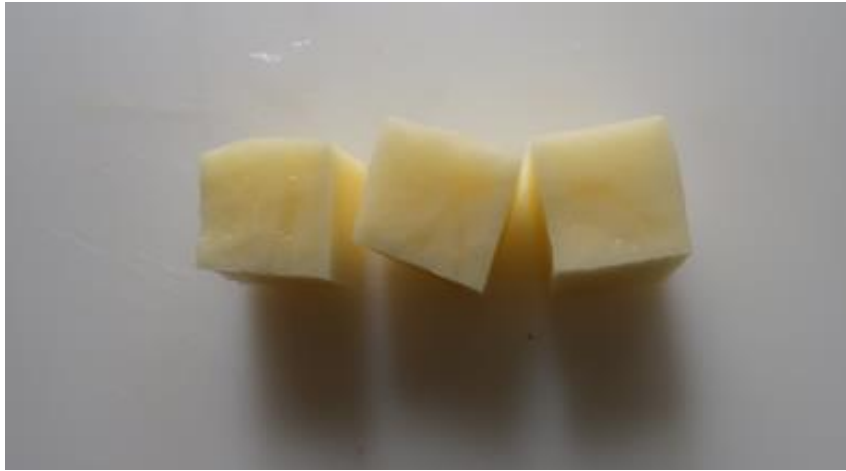


Kenya (2021)



Kenya (2021)






Boiled and fried potato (2021)

# Breeding and testing strategies

## Screening methods




**Field assessment of resistance in potato to *Phytophthora infestans***

**International Cooperators Guide**


G.A. Forbes · W. Pérez · J. Andrade-Piedra

INTERNACIONAL  
CENTRO  
CIP  
A member of the  
CGIAR Consortium



**Procedures for Standard Evaluation and Data Management of Advanced Potato Clones**

**Module 2. Healthy Tuber Yield Trials**  
**International Cooperators' Guide**



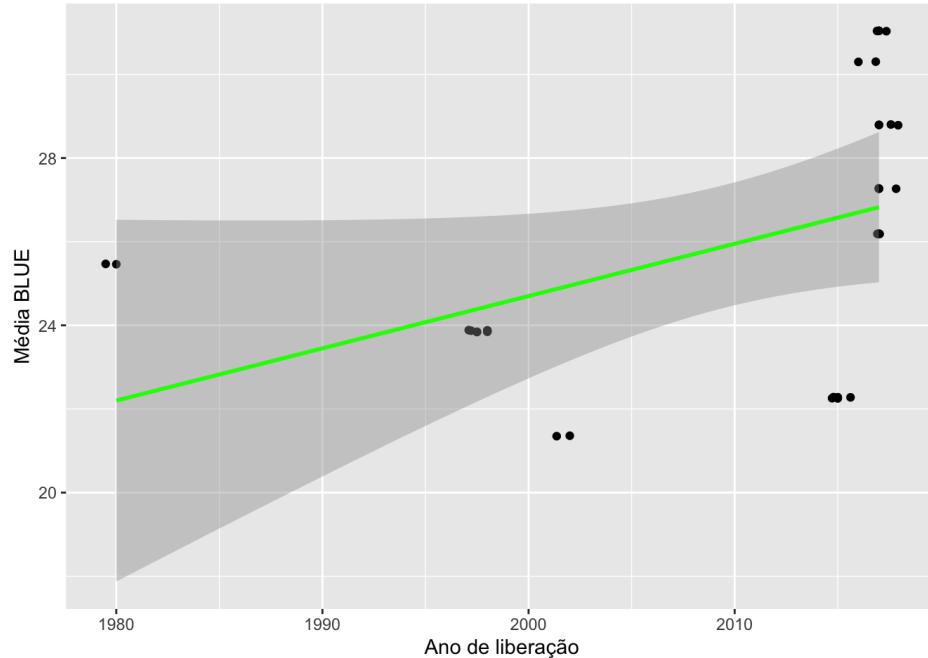
**Procedures for Standard Evaluation and Data Management of Advanced Potato Clones**

**Module 4. Assessment of Dormancy and Sprouting Behavior of Elite and Advanced Clones**

<https://research.cip.cgiar.org/potatoknowledge/protocols.php>

# Genetic gain and performance of advance materials

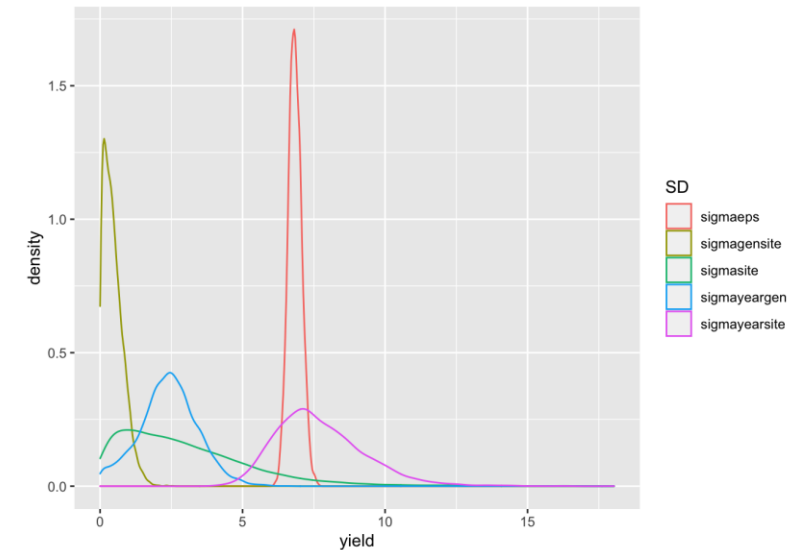
## NPT HISTORICAL DATA



Genetic gain (%) = 0.56 per year  
Baseline=22.2 t/ha

```
summary(m1.1)$coefficients (Table)
## Estimate Std. Error t value Pr(>|t|)
## (Intercept) -225.274154 130.69210922 -1.723701 0.10402672
## ano2 0.124987 0.06503622 1.921807 0.07262434
```

```
## Estimate Std. Error t value Pr(>|t|) (Table and processing)
## (Intercept) -347.5350953 111.65819087 -3.112491 0.005733197
## ano2 0.1879235 0.05566048 3.376247 0.003170223
```



# Genetic gain and performance of advance materials

## PRODUCT PIPELINE

Key Competitive Products	Geografic targets	Agro-climatic zone being targetted	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
			<i>Development &amp; Early Product Testing</i>	<i>Early Product Testing</i>	<i>Late Product Testing</i>	<i>Late Product Testing</i>	<i>External Testing</i>	<i>Product Introduction</i>
Shangi/ NAROPOT4/ Kinigi/Jalene	Africa Highlands (Kenya, Rwanda, Ethiopia, Uganda, Tanzania)	Highland	4200 (SAP)	125 (SAP)	57 (SAP) 20 (Biofortified)	CIP312284.737 CIP312084.731 CIP313001.649 CIP313011.28 CIP314938.14		CIP392797.22 (Unica) CIP393371.157 (Wanjiku)
Sherekea/Unica	Sub-saharan Africa	Mid Elevation		20 (LTVR)				CIP392797.22 (Unica) CIP398208.704 (Chulu) CIP398190.200 (Nyota)
Shangi/ NAROPOT4/ Kinigi/Jalene	African highlands	Highland		215 (B)				

# Breeding challenges and progress

## CWR PROJECT - POTATO WILD RELATIVES

### Bacteria wilt

- *S. commersonii*, *phureja*, *tuberosum*

### Drought

- *S. Boliviense* (TS=3233)
- *S. bukasovii*
- *S. infudibuliforme*
- *S. lignicaule*
- *S. Raphanifolium* (TS=5513)
- *S. Tacnaense* (TS=4524)
- *S. Tarapatatum* (1903)

### Late blight (LB)

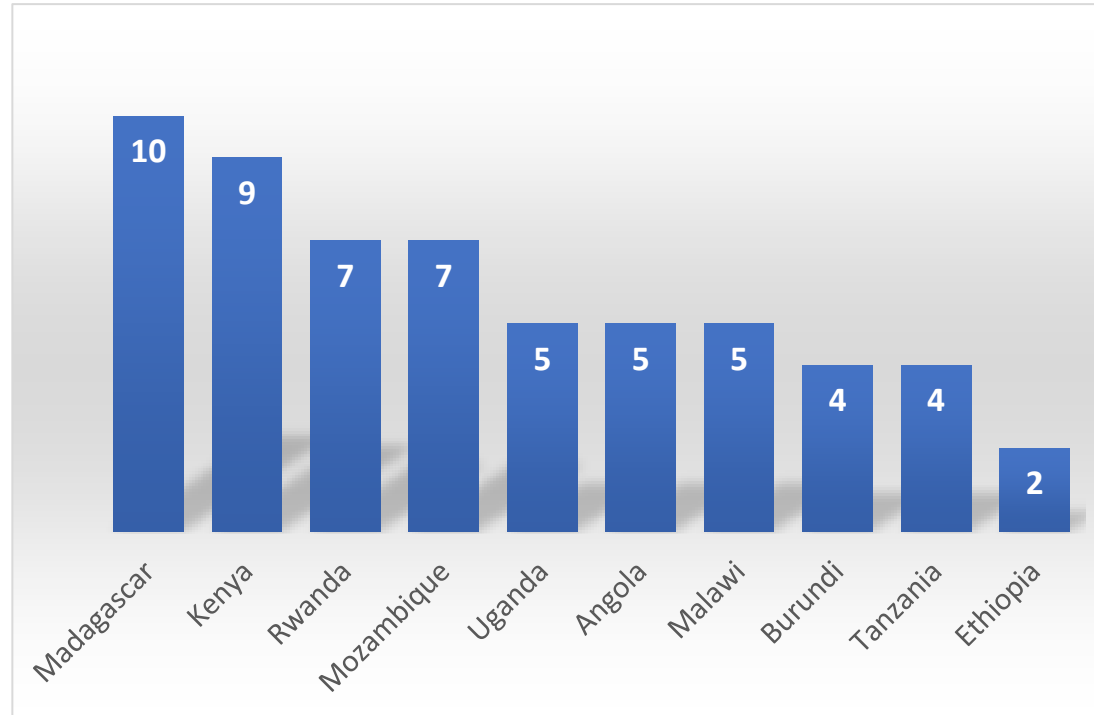
- *S. microdontum*
- *S. tarijense*
- *S. megistacrolobum*
- ***S. stn, chq*\* Fam1 =132**
- ***S. phu, pcs*\* Fam2=143**
- ***S. 2xhyb, cjm*\* Fam4=150**
- ***S. stn, sgr*\* Fam3=100**

### LB-PVS

- *adg, tbr, dms, stn, sgr*
- *adg, tbr, dms, 2xHyb, cjm*

# SSA released varieties

2010 ONWARDS

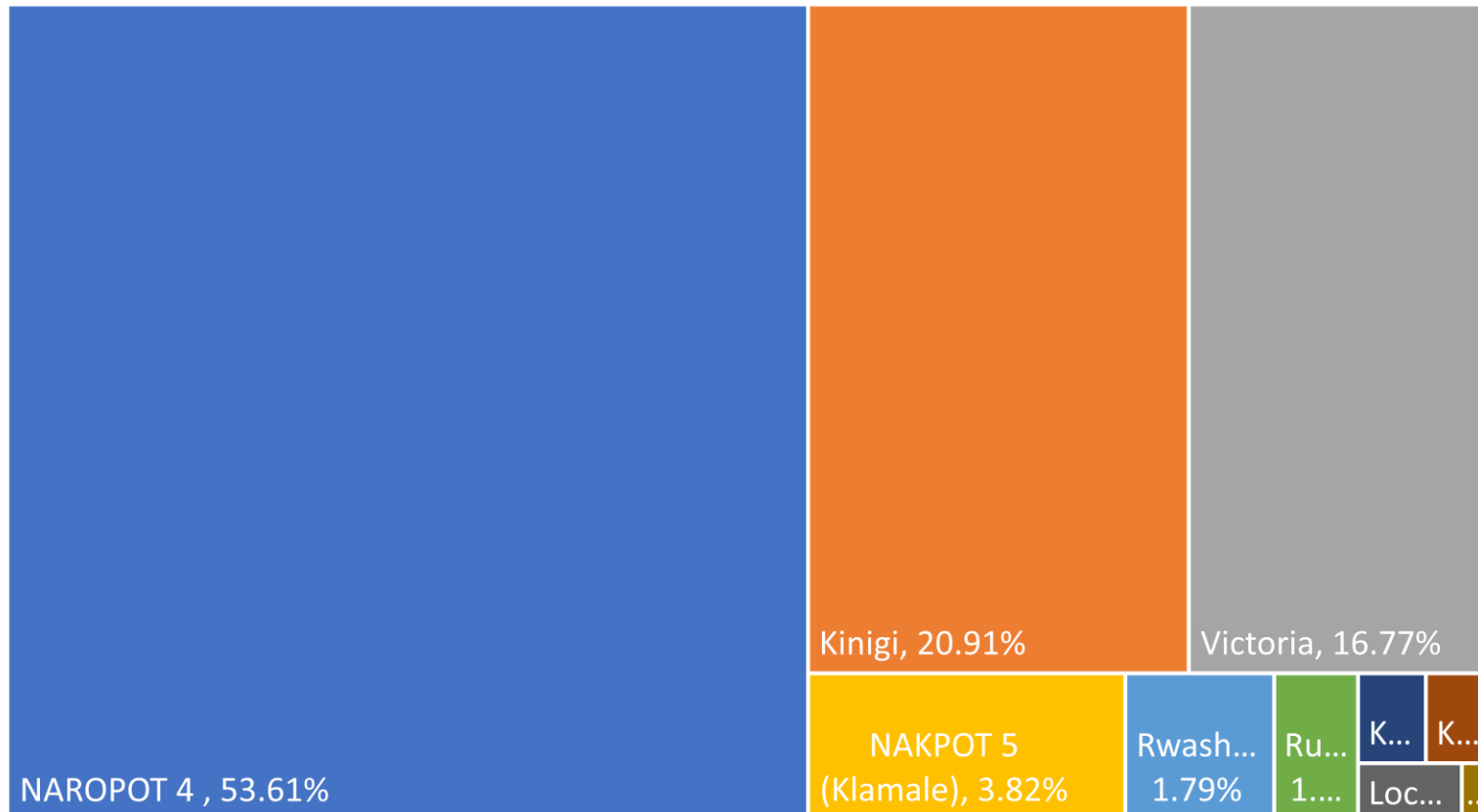


**Variety development strategy**  
**Advanced product meeting**

Country	Variety	CIPcode	Released
Angola	Boa Branca	CIP371056.175	2013
	IIA 50	CIP393227.44	2013
	Rosa	CIP395015.6	2013
	Preferencia Chevron	CIP395111.13	2013
Ethiopia	Barcelinha	CIP396036.201	2013
	BABU	CIP384321.3	2011
Kenya	Dagem	CIP396004.337	2013
	Purple Gold	CIP391691.96	2010
	UNICA	CIP392797.22	2015
	Konjo	CIP393077.159	2015
	Lenana	CIP393079.4	2017
	Wanjiku	CIP393371.157	2017
	Kenya Mpya	CIP393371.58	2010
	Sherekea	CIP393385.39	2010
	Nyota	CIP398190.200	2017
	Chulu	CIP398208.704	2017
Malawi	Thandizo	CIP381381.13	2011
	Zikomo	CIP381381.20	2011
	Chuma	CIP395015.6	2011
	Njuli	CIP396027.205	2011
	Mwai	CIP396036.201	2011
Mozambique	Lulimile	CIP381381.13	2011
	Angonia	CIP384321.19	2011
	Wa Kaya	CIP393077.54	2011
	Kolophete	CIP395011.2	2011
	Chitukuko	CIP395015.6	2011
	Laldas	CIP800923	2011
	Calinga	CIP800946	2011
Rwanda	Kazeneza	CIP393077.159	2019
	Nkunganire	CIP393280.64	2019
	Twihaze	CIP393371.58	2019
	Izihirwe	CIP396018.241	2019
	Ndeze	CIP398190.615	2019
Tanzania	Tengeru	CIP381381.13	2012
	Asante	CIP381381.20	2012
	Meru	CIP393371.58	2012
	Sherekea	CIP393385.39	2012
Uganda	Naropot1	CIP396038.107	2015
	Naropot2	CIP393280.82	2015
	Naropot3	CIP396034.103	2015
	Naropot4	CIP388778.9	2016
Madagascar	Meva*	CIP377957.5	*
	Avotra	CIP381381.13	*
	Diamondra*	CIP381381.20	*
	Fanja	CIP391919.3	*
	Marotia	CIP392797.22	*
	Maneva Harena*	CIP393371.58	*
	Bemanga	CIP394903.3	*
	Valisoa	CIP395111.13	*
Spunta	CIP800923	*	

# Varietal Adoption

UGANDA 2019



Gatto et al. 2019. Workshop report -  
Varietal Release & Adoption in Uganda



# Breeding challenges and progress

- **Product profiles** and stage-gates defined (++)
- Product advanced meeting and **Breeding pipeline** (+)
- **Statistical design (row-column) and analysis (mixed models, BLUPs, Index Selection)** (+++)
- Breeding strategy for population improvement (Cohort) (+)
- Genomic Selection/MAS (+)
- Data management systems (<https://www.potatobase.org/>) (+++)
- **Barcoding (plots and samples)** (+++)
- **New breeding facilities (UoN and KEPHIS)** (++)
- Public- Private partnership (++)
- MET – selecting new field (+++)
- Tissue culture lab improvement (+)
- Cold room for tuber seed storage (+)

# Partnerships

- KALRO (Kenya) – Moses Nyongesa and Susan Otieno
- NARO (Uganda) – Alex and Prossy Namugga
- EAIR (Ethiopia) – Atsedo Solomon and Tesfaye Desta
- RAB (Rwanda) – Theophile Ndacyayisenga and Placide Rukundo
- HZPC (The Netherlands) – Jeroen Wolfkamp





Thank you



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