Generation

Embrapa
Cassava & Tropical Fruits

Ministry of Agriculture,
Livestock and Food Supply

BRASIL
BRAZILIAN GOVERNMENT

Cassava Drought Physiology


Photo: Revista Veja 2004

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Embrapa Cassava & Tropical Fruits

30 September 2005

Embrapa - Brazilian Agricultural Research Corporation

- **Coordenation of the Brazilian Agricultural Research System**

Embrapa Headquarters

09 National Thematic Centers

15 National Product Centers

13 Agroforesty or Ecorregional Research Centers

03 Special Services Centers

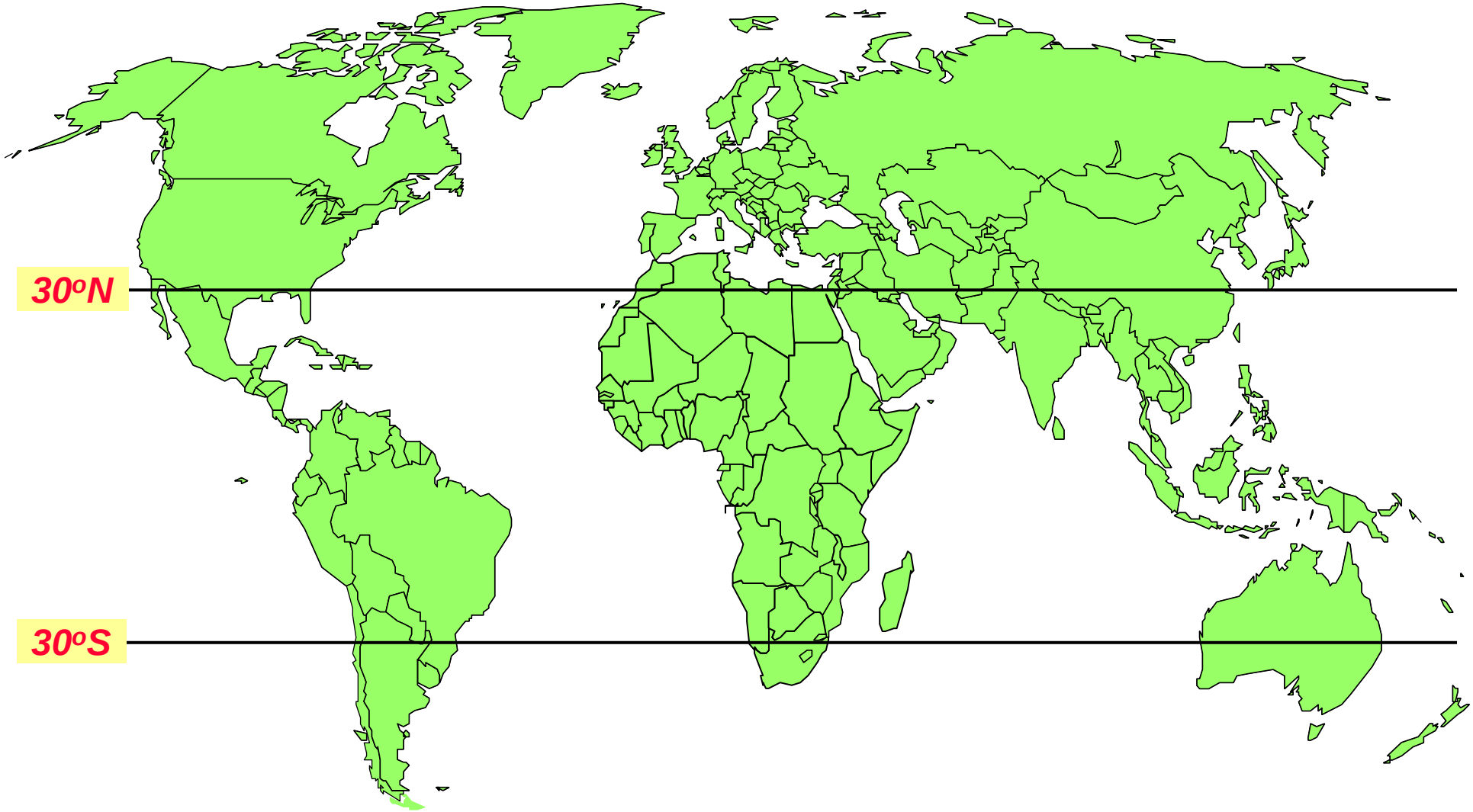
17 State Ag. Research Organizations

National Center for Cassava and Tropical Fruit Crop Research (CNPMF)

Embrapa Cassava & Tropical Fruits

2004: Cassava World Production: 195 million tons

Harvest Area: 18 million ha



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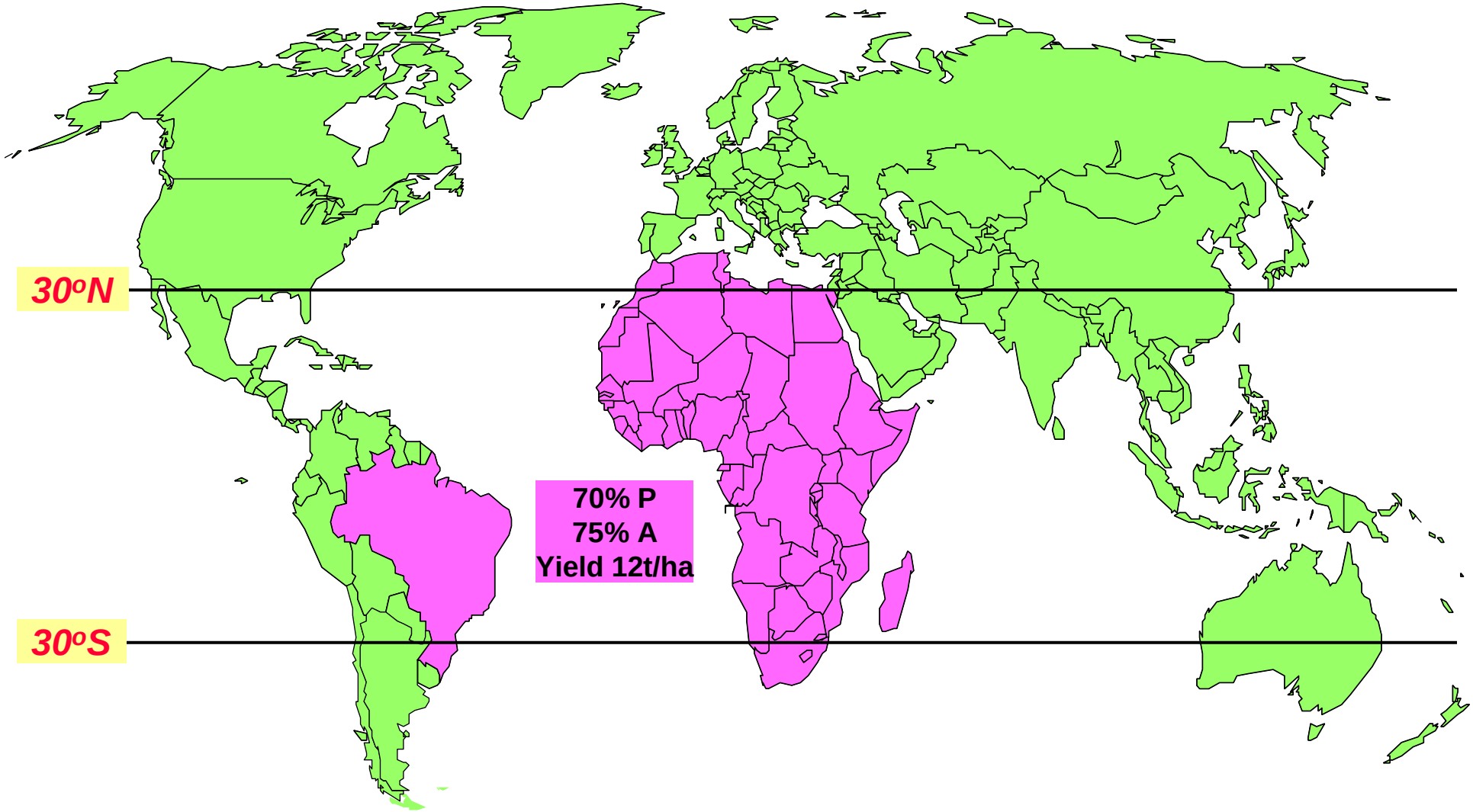

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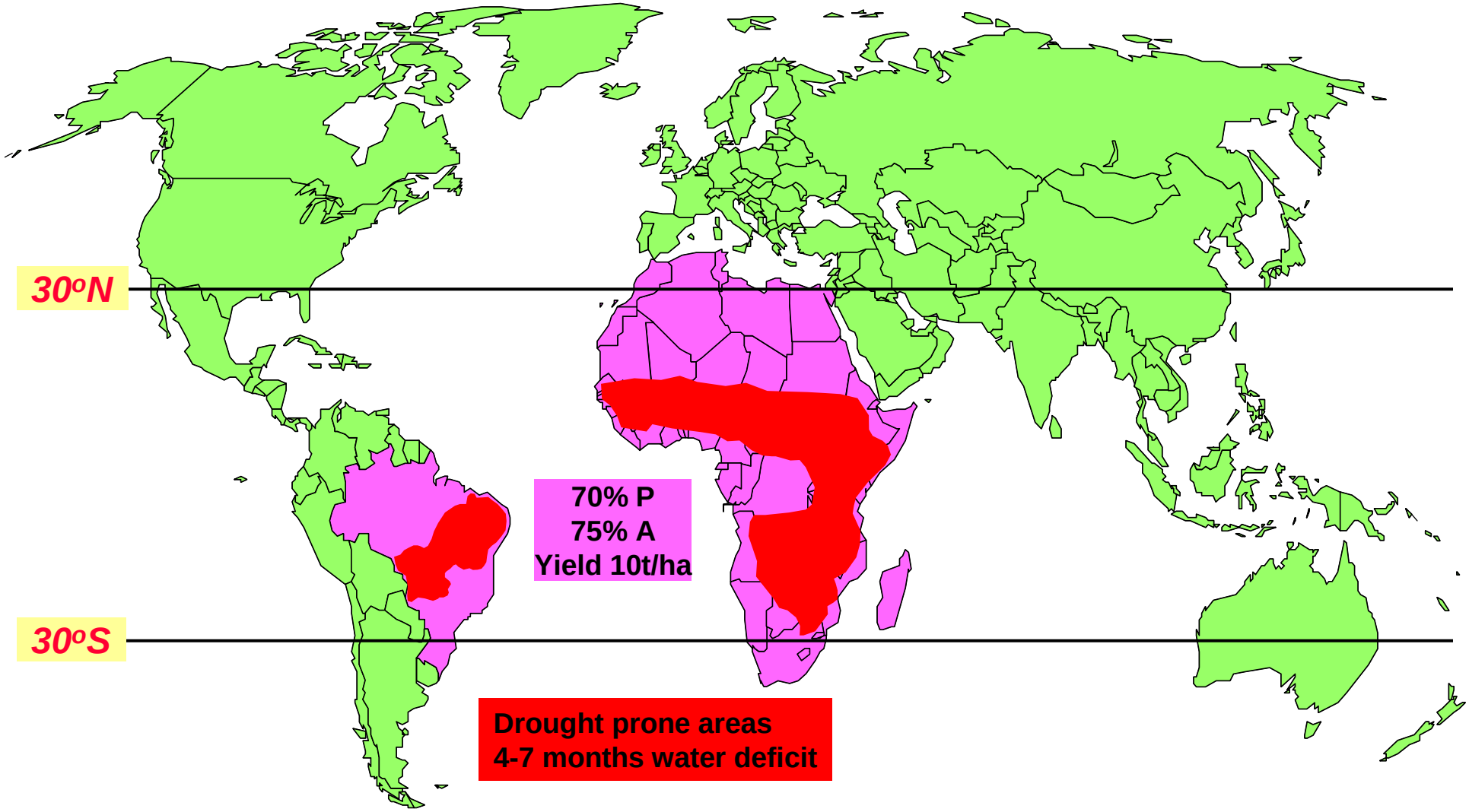


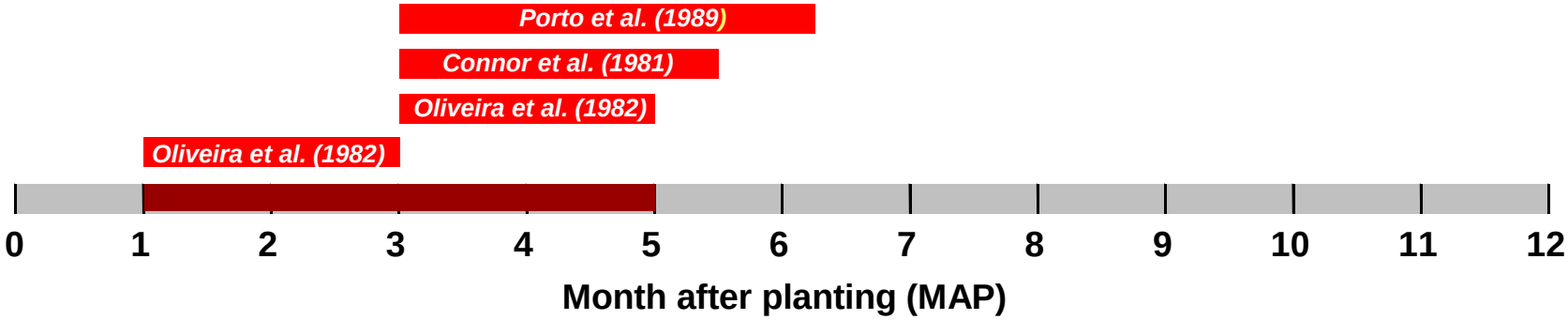
Potential of produtivity

Crop	Maximum Annual Yield (t/ha)	Daily Energy Production (kJ/ha)
Cassava (fresh root)	71	1045
Maize (dry grain)	20	836
Sweet potato (fresh root)	65	752
Rice (dry grain)	26	652
Sorghum (dry grain)	13	477
Wheat (dry grain)	12	460
Banana (fruit)	39	334

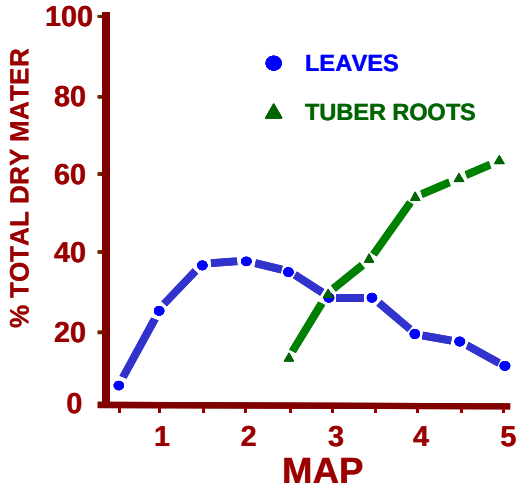
Source: de Vries et al. (1967)

Water Deficit *vs* Yield

Water deficit ➡ Tuber yield reduction: 30 to 60%

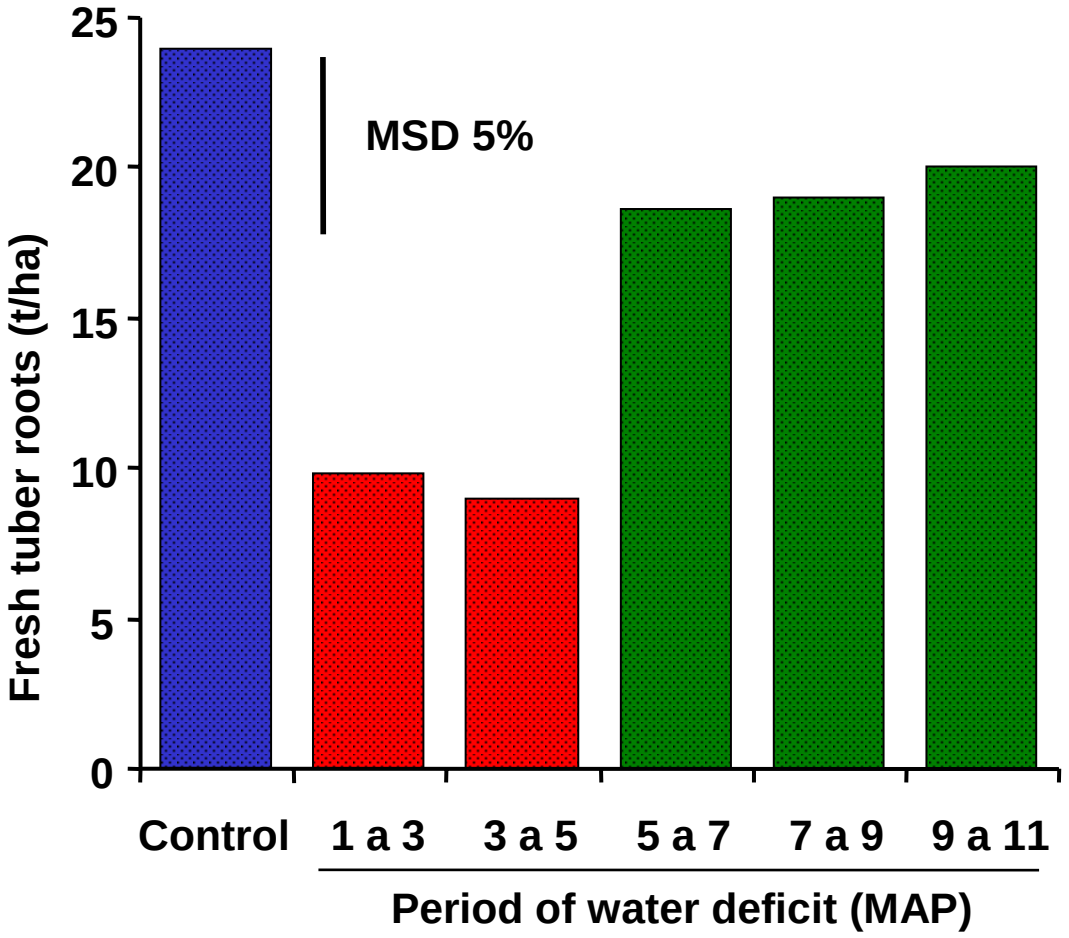


Rapid leaf growth; Tuber roots bulking



2 to 3 MAP: start bulking

Water Deficit *vs* Critical Period



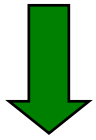
Source: Oliveira et al, 1982

Cassava *vs* Water Deficit

Water available → high stomatal conductance → keep high internal CO_2 concentration

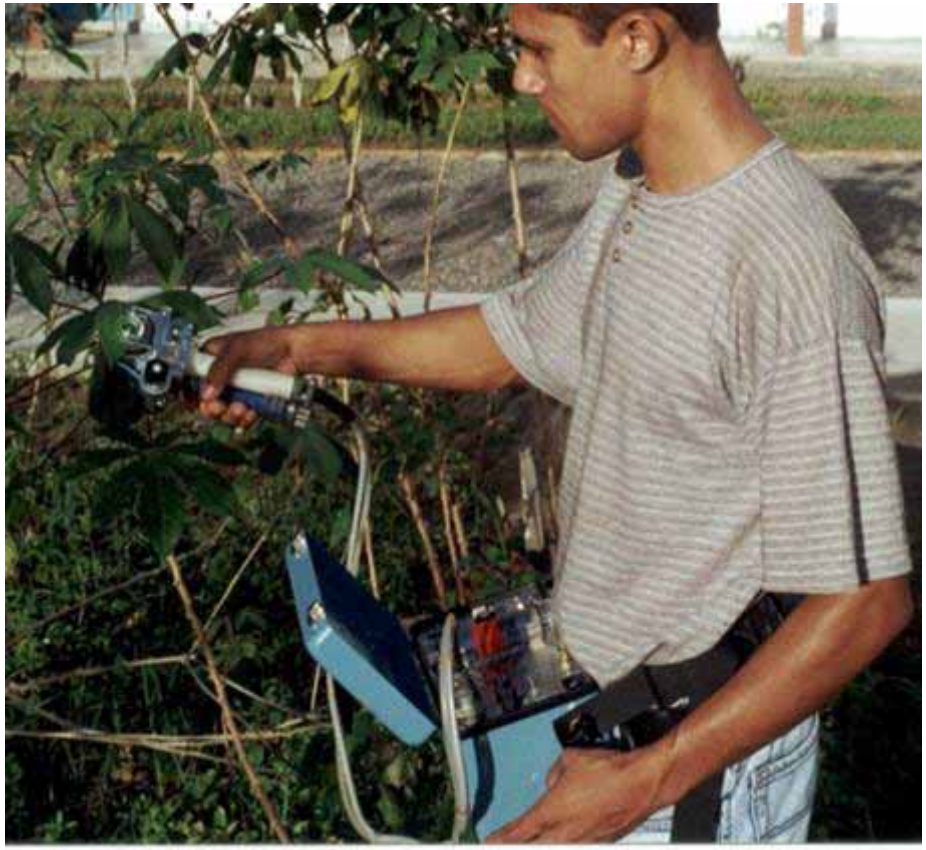
Water deficit → close stomata → decrease water loss and internal CO_2 → decrease leaf area growth

Considerable variation in stomatal conductance



Leaf conductance: useful to pre-select germplasm conferring adaptation to prolonged dry periods

Cassava *vs* Water Deficit



Diffusion Porometer

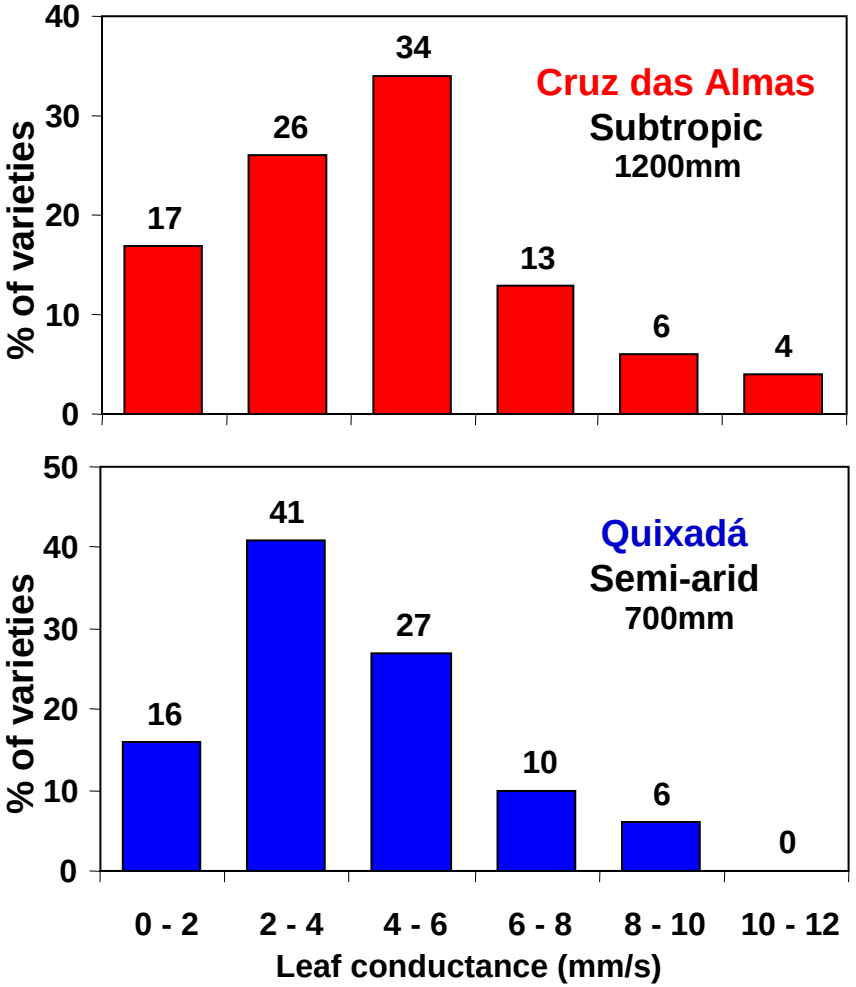
Estimate leaf condutance

Cassava *vs* Water Deficit

Leaf Conductance in Cassava Germplasm

Subtropic (1200mm)
Cruz das Almas, Brazil

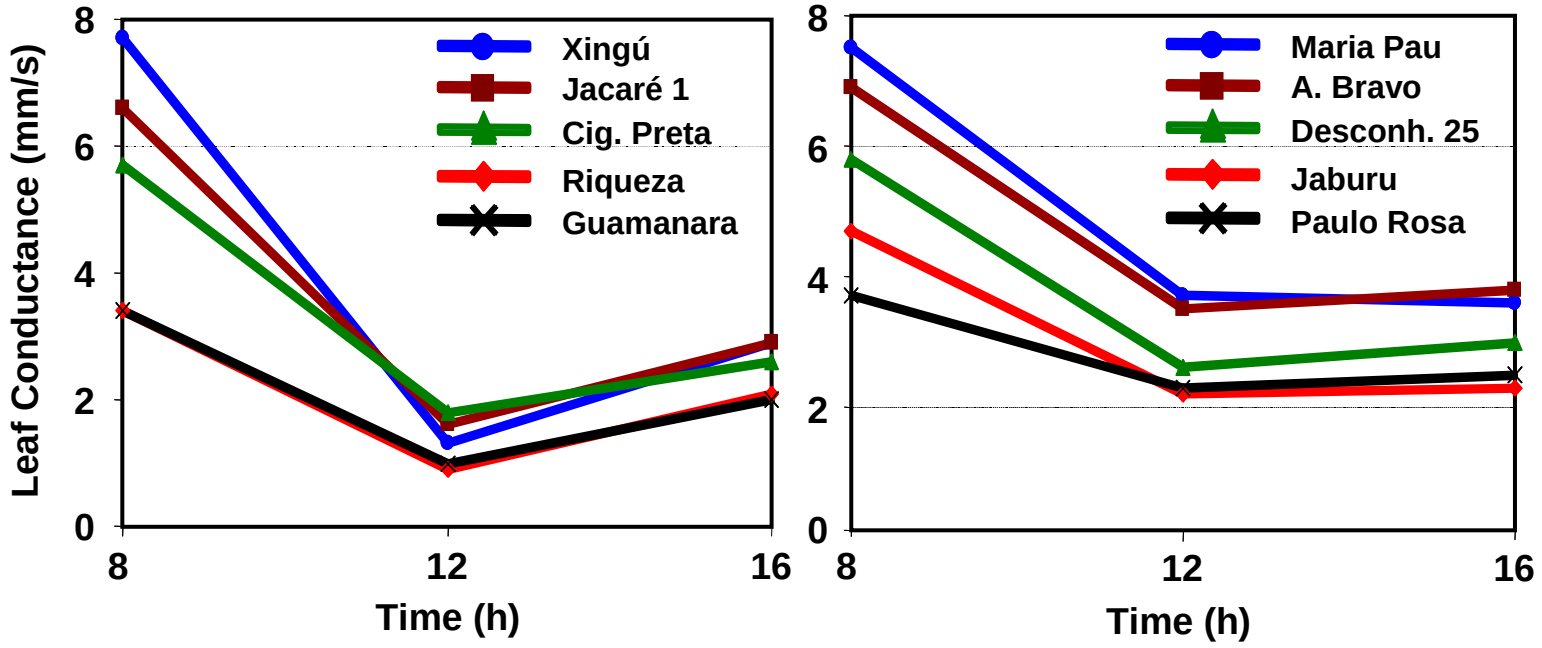
Semi-arid (700mm)
Quixadá, Brazil



Source: Alves, 1982

Cassava *vs* Water Deficit

Leaf conductance in Cassava – Daily Variation



Source: Alves & Porto, not published

Cassava *vs* Water Deficit

Leaf conductance in Cassava - Quixadá, Semi-arid – 5 MAP

Genotype (BGM)	L.Cond. (mm/s)
391	8.82
274	8.65
480	8.14
329	7.31
590	7.14
016	6.33
289	6.29
043	5.98
031	5.60
Test	5.57
025	5.55
461	5.31
048	5.26
613	5.24
166	5.23
076	5.00
047	4.70

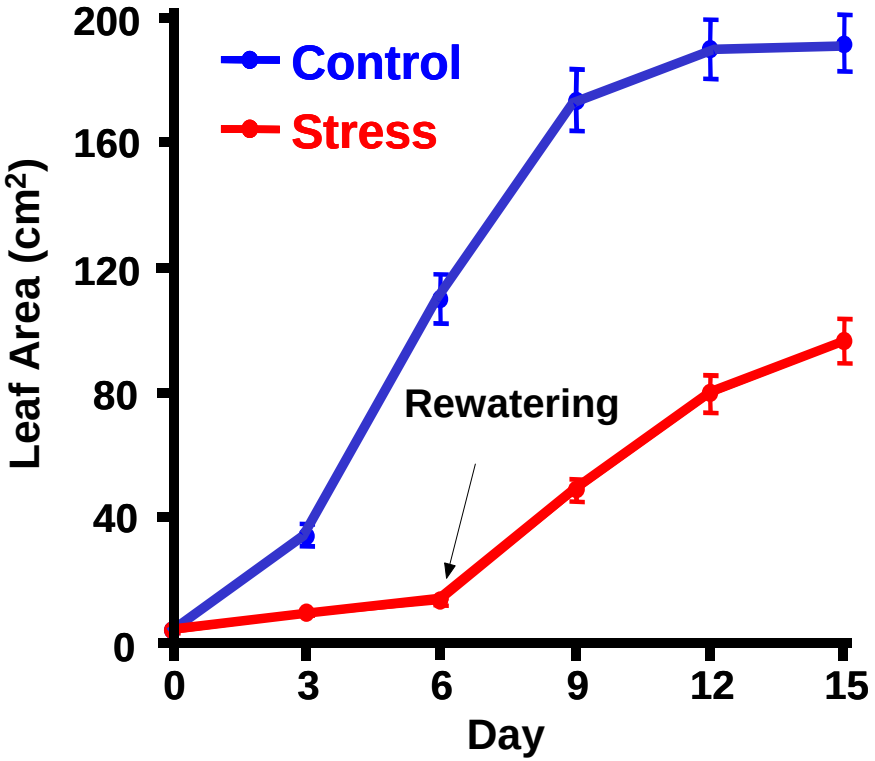
Genotype (BGM)	L.Cond. (mm/s)
384	4.64
433	4.63
215	4.45
598	4.22
612	3.86
178	3.84
071	3.81
537	3.70
010	3.52
278	3.48
123	3.37
260	3.17
023	2.95
004	2.81
233	2.80
161	2.75

Genotype (BGM)	L.Cond. (mm/s)
116	2.74
279	2.54
449	2.38
254	2.36
083	2.29
080	2.26
505	2.23
196	2.01
398	1.95
143	1.94
331	1.87
275	1.73
307	1.59
001	1.49
458	0.86
119	0.61

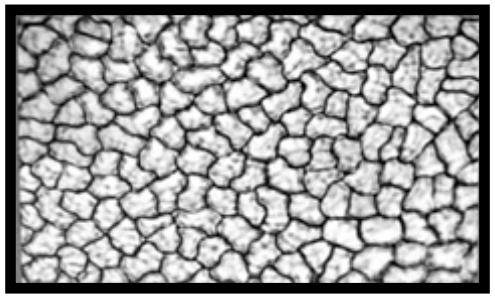
Source: Alves, 1982

Cassava *vs* Water Deficit

Leaf and Cell Growth



Fully expanded
Adaxial epidermis



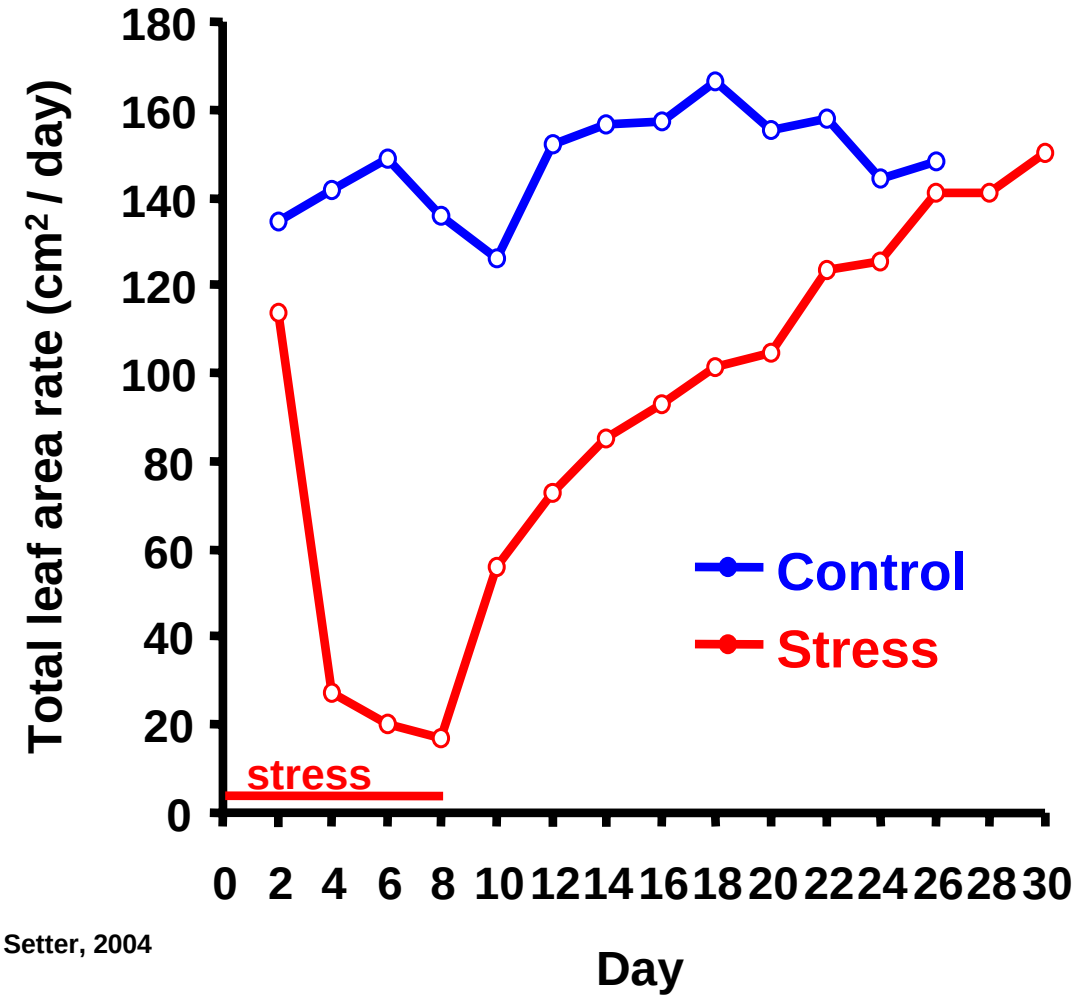
Control

Stress

Source: Alves, 1998

Cassava *vs* Water Deficit

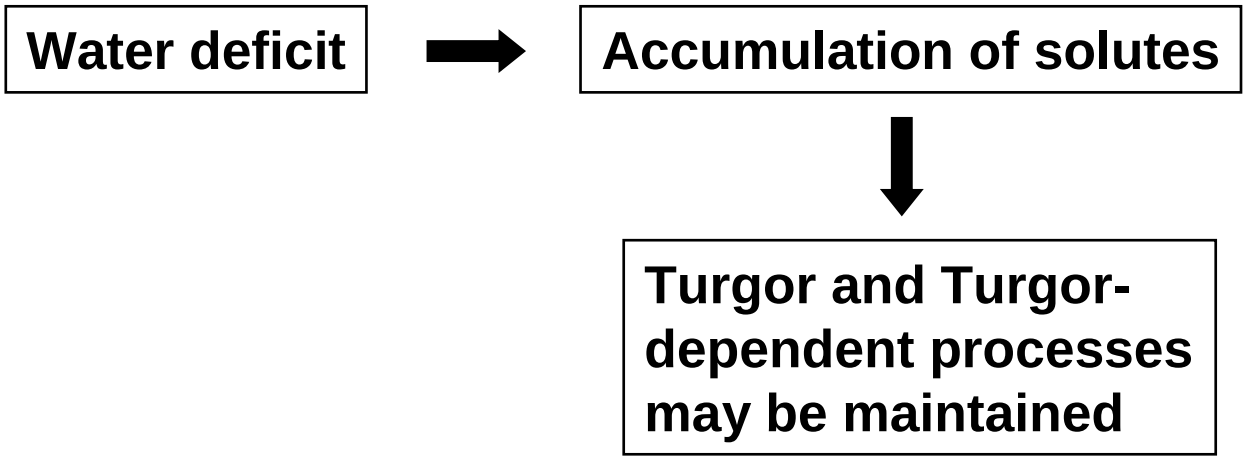
Total Leaf Area



Source: Alves & Setter, 2004

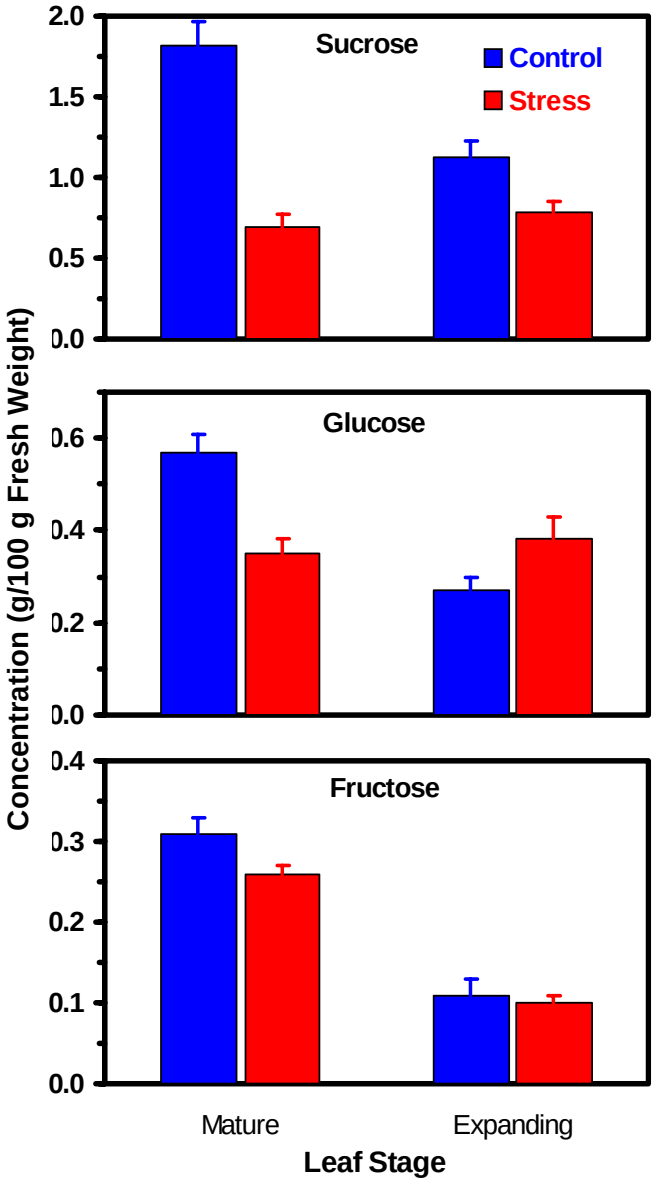
Cassava *vs* Water Deficit

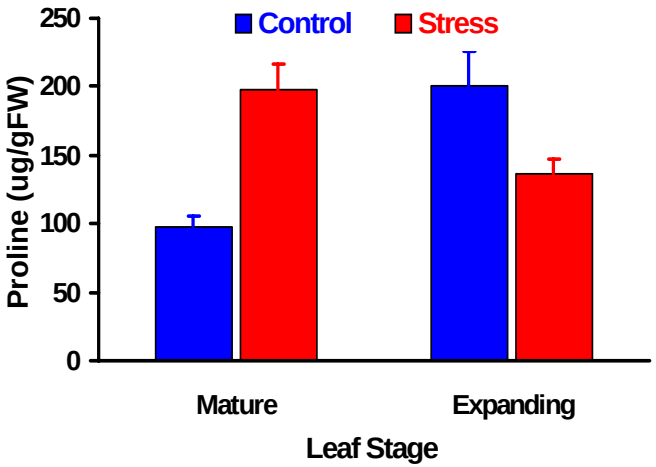
Osmotic Adjustment

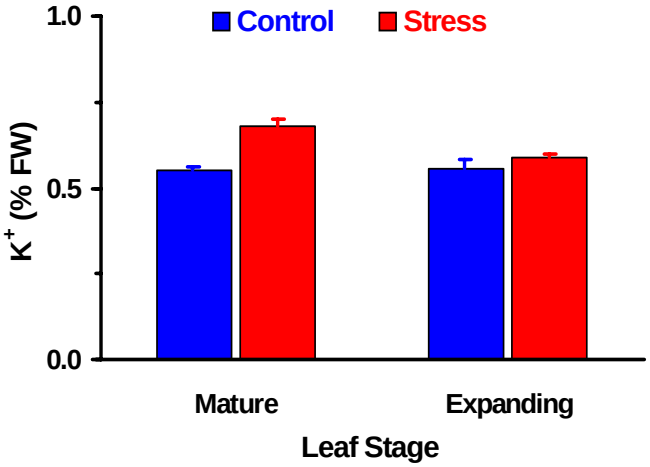


$$\text{Osmotico Adjustment} = \Psi_{osm\ (control)} - \Psi_{osm\ (stress)}$$

Osmotic Adjustment – Solutes accumulation in Cassava



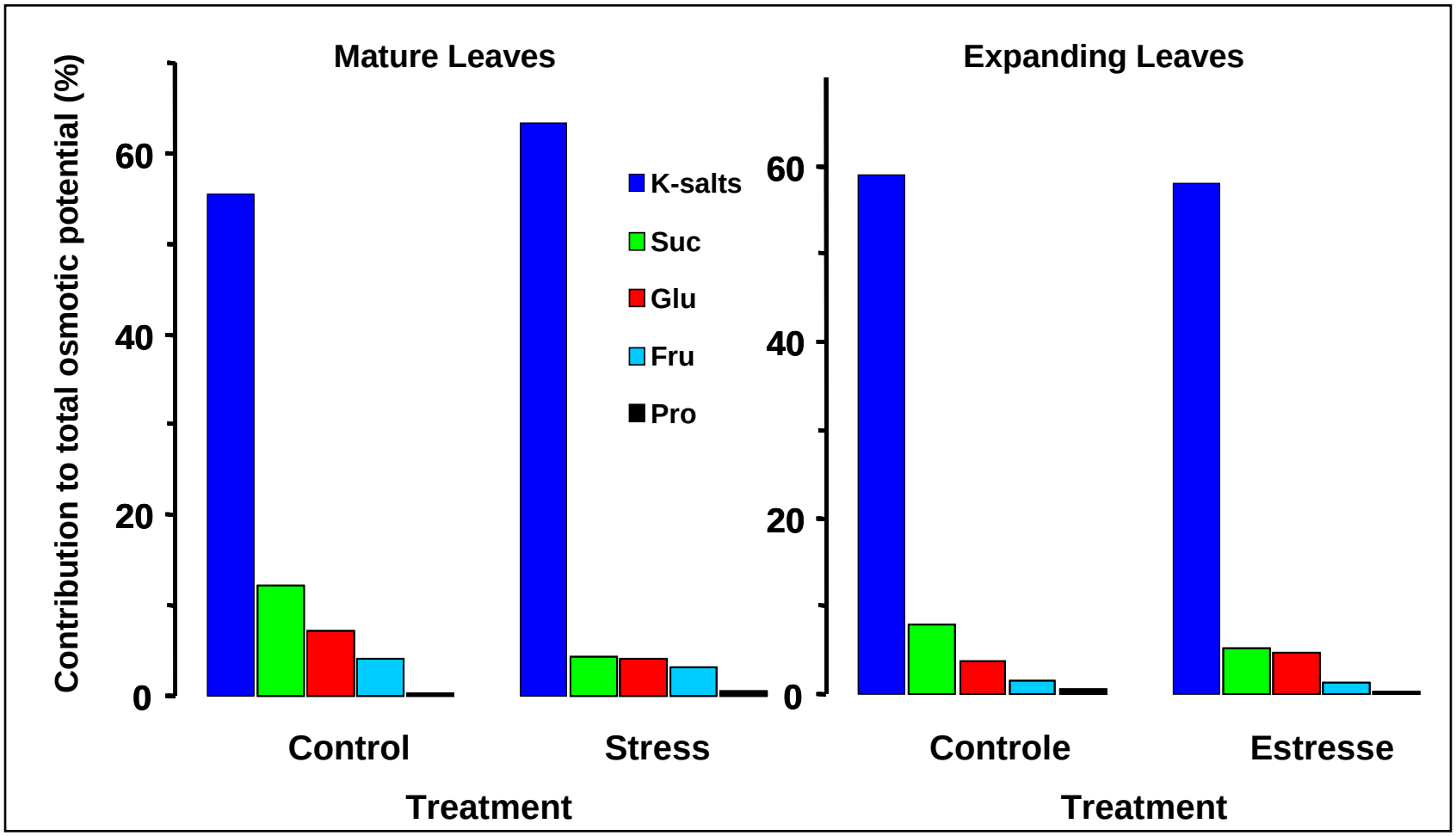




Source: Alves, 2004

Osmotic Adjustment

Solute contribution to the total osmotic potential in cassava



Source: Alves, 2004

Cassava *vs* Water Deficit

Abscisic Acid (ABA) Accumulation

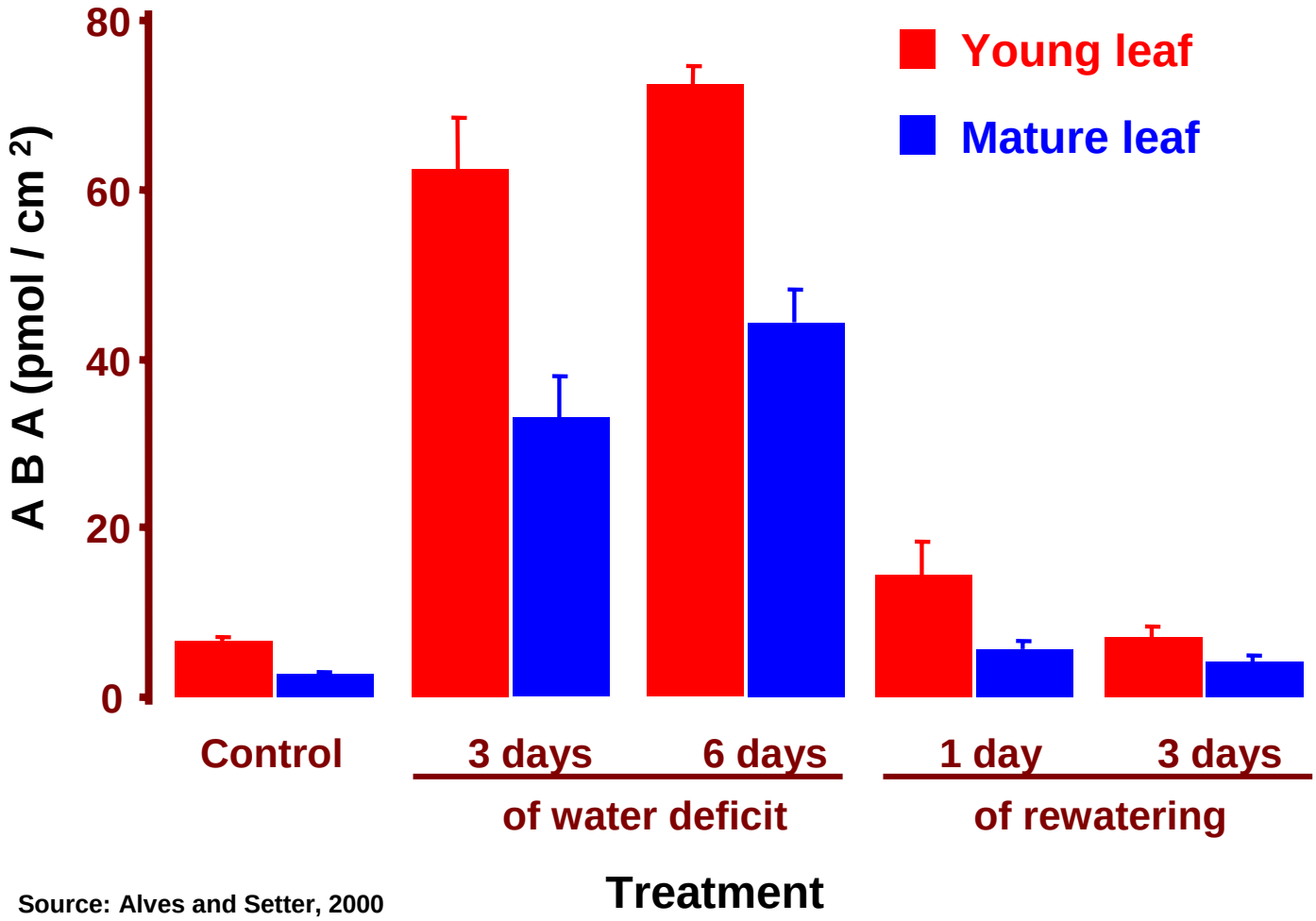
ABA external application To well watered plants ⟶ **Drought Responses**

- Restricted growth of shoots
- Reduction of leaf area
- Stimulation of root extension
- Lateral root growth
- Root hair development

ABA → stress hormone in plants

Cassava *vs* Water Deficit

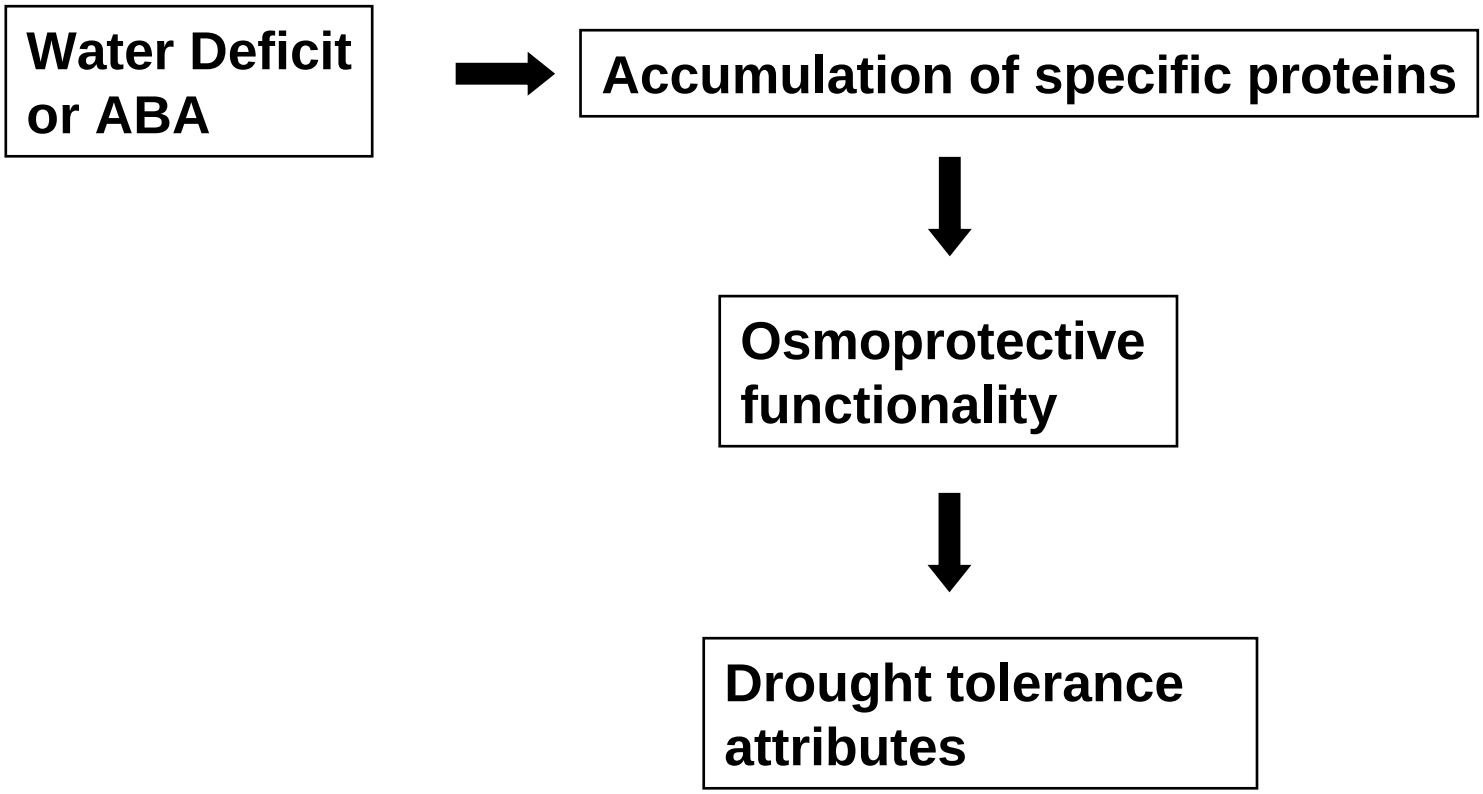
ABA Accumulation in Cassava



Source: Alves and Setter, 2000

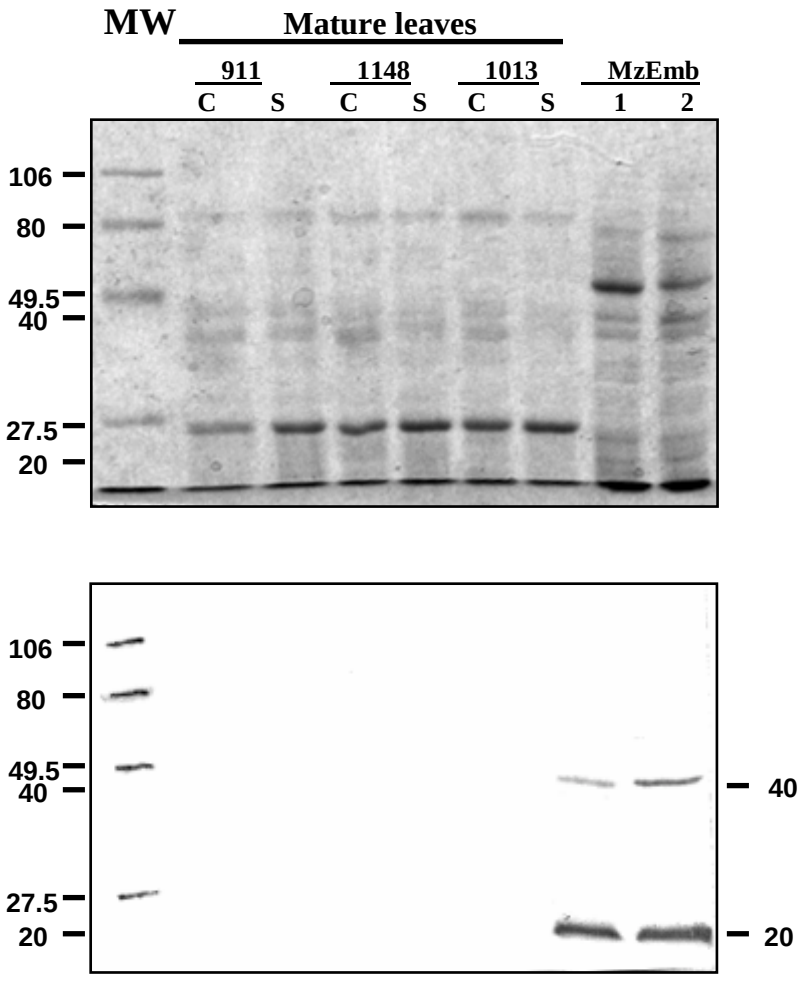
Cassava *vs* Water Deficit

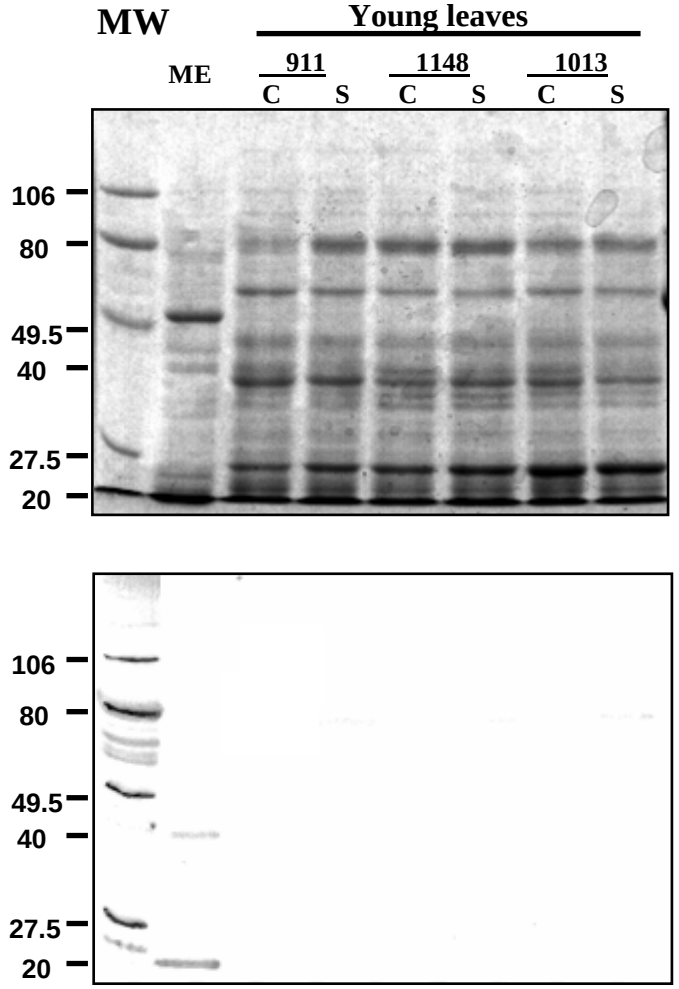
Low MW Proteins Accumulation



Low MW Proteins Accumulation

Dehydrin Western Blot in Cassava





Source: Alves and Setter, 2004

Other parameters related to drought tolerance

Leaf longevity → Leaf Retention

Early Bulking → Carbohydrate Translocation

Root depth → Root growth

Other parameters related to drought tolerance

Leaf longevity → Leaf Retention

Leaf retention capacity can add 7 t/ha of fresh roots

Source: H. Ceballos

Leaf longevity → Leaf Retention

ETH-Zurich, Switzerland

Transgenic cassava expressing ipt gene (cytokinin production)

Delayed chlorophyll degradation

After 2 weeks in the dark

Prolonged leaf longevity

After 1-month of drought

Induced early bulking

3 month old plants

Photos: Zhang e Gruissem

Source: Zhang e Gruissem, 2004

Identifying the physiological and genetic traits that make cassava one of the most drought tolerant crops

GCP Project #3 Competitive Grant

Main Objectives:

- *Find the best biological traits for improving drought tolerance by MAS*
- *Identify trait-marker associations for the development of a more cost-effective breeding process for drought tolerance that can be used for cassava and other crops*

Intended outputs:

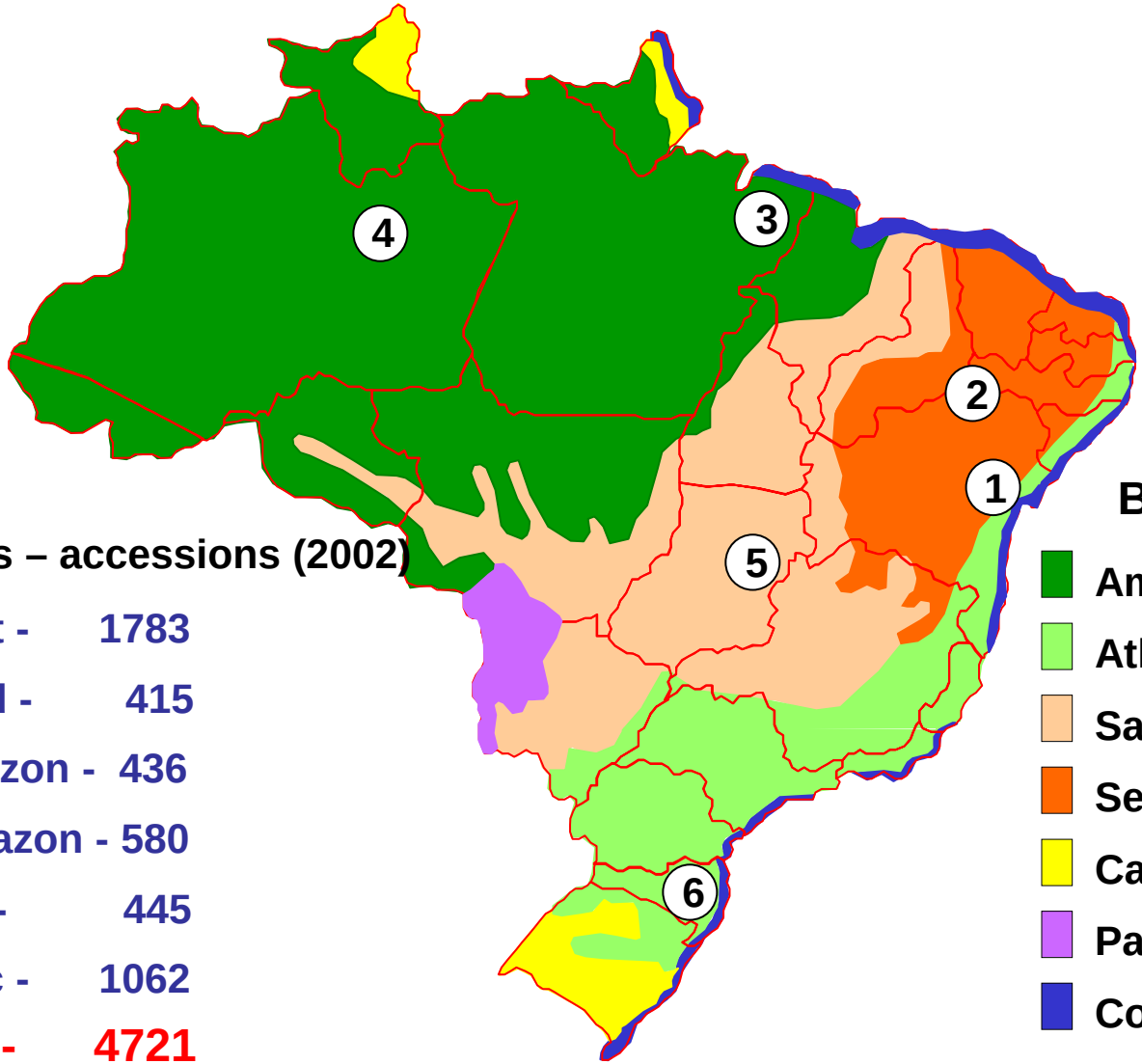
- *Improved understanding of the drought tolerance mechanisms in cassava and their potential use in other crops*
- *Cassava genotypes with wide diversity for drought tolerance traits*
- *Molecular markers associated with drought tolerance genes identified*
- *Assessment of the effect of the leaf retention gene for improving drought tolerance*
- *Strengthening building capacity and partnership among institutions involved with breeding for drought tolerance*

Activities / Methods

1. Better knowledge of the drought tolerance mechanisms

- *Selection of contrasting genotypes for drought tolerance*
- *30 contrasting genotypes → 20 tolerants e 10 susceptibles*
- *Evaluations (field and greenhouse) under controlled conditions*
- *Parameters*
  - *Leaf conductance; transpiration; photosynthesis*
  - *Solutes accumulation*
  - *Accumulation of specific low MW proteins*
  - *ABA accumulation*
  - *Nonstructural carbohydrate reserves in leaves*
  - *Leaf area; leaf retention; root depth; # of roots; Dry matter; Starch; Productivity; Tolerance to CGM and other insects*

Cassava Brazilian germplasm collection



Regional Banks – accessions (2002)

1. Northeast - 1783
2. Semi-Arid - 415
3. East Amazon - 436
4. West Amazon - 580
5. Savanna - 445
6. Subtropic - 1062

Total - 4721

Cassava Brazilian germplasm collection

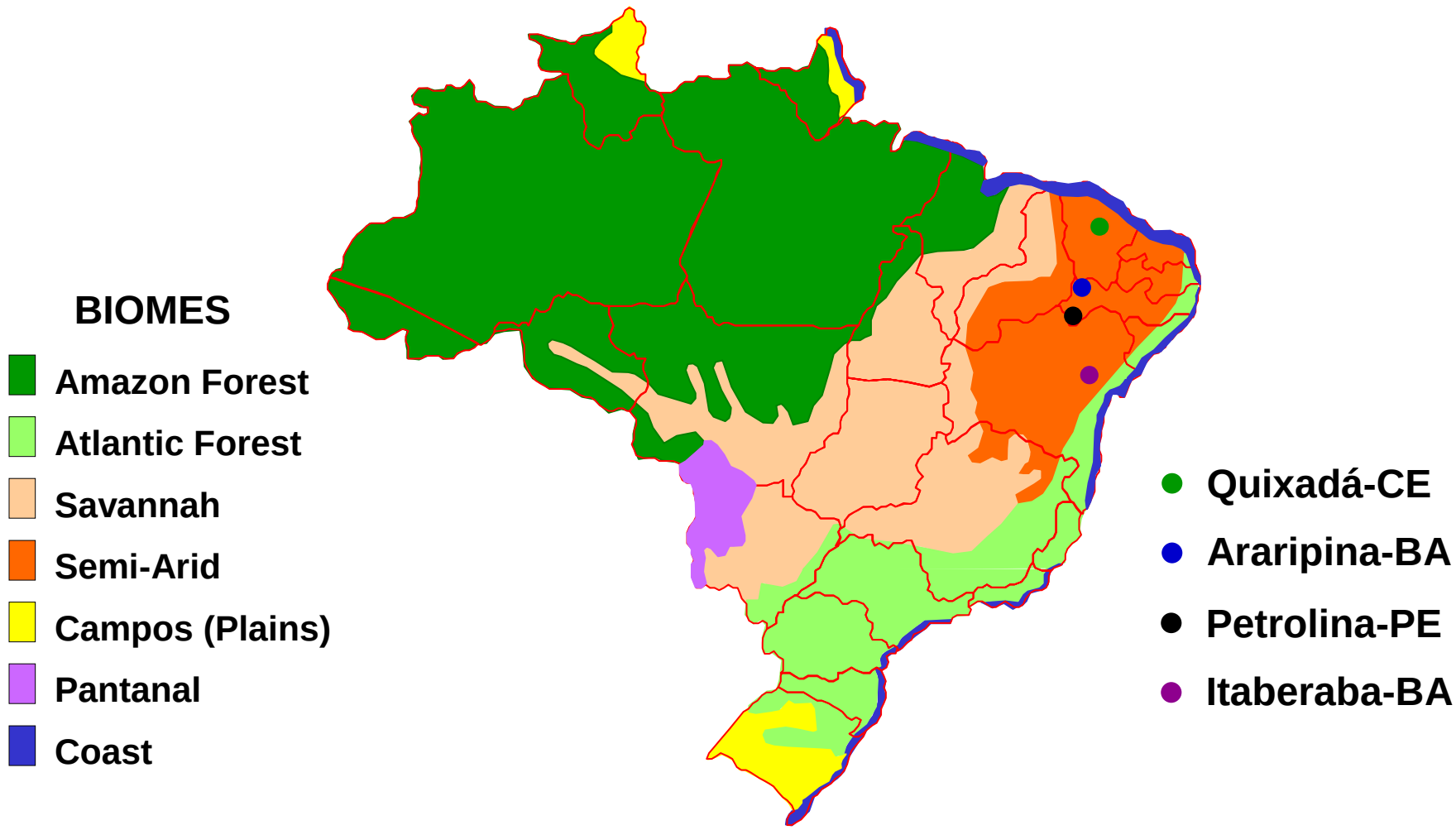
Field conservation

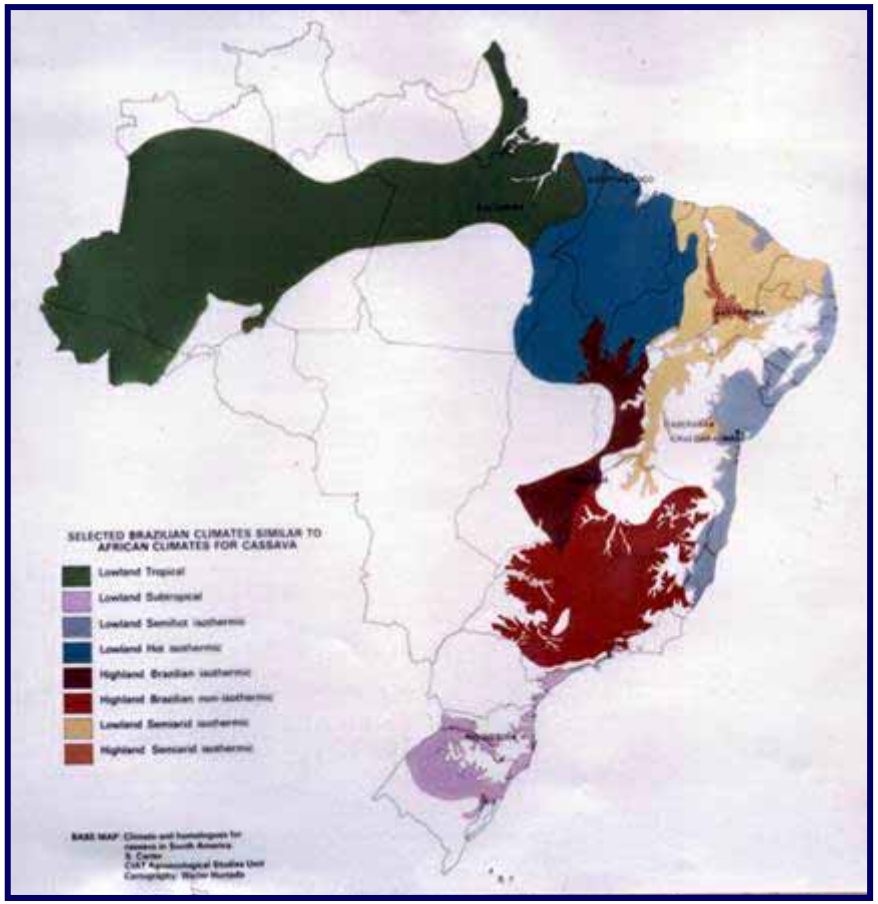
In vitro conservation

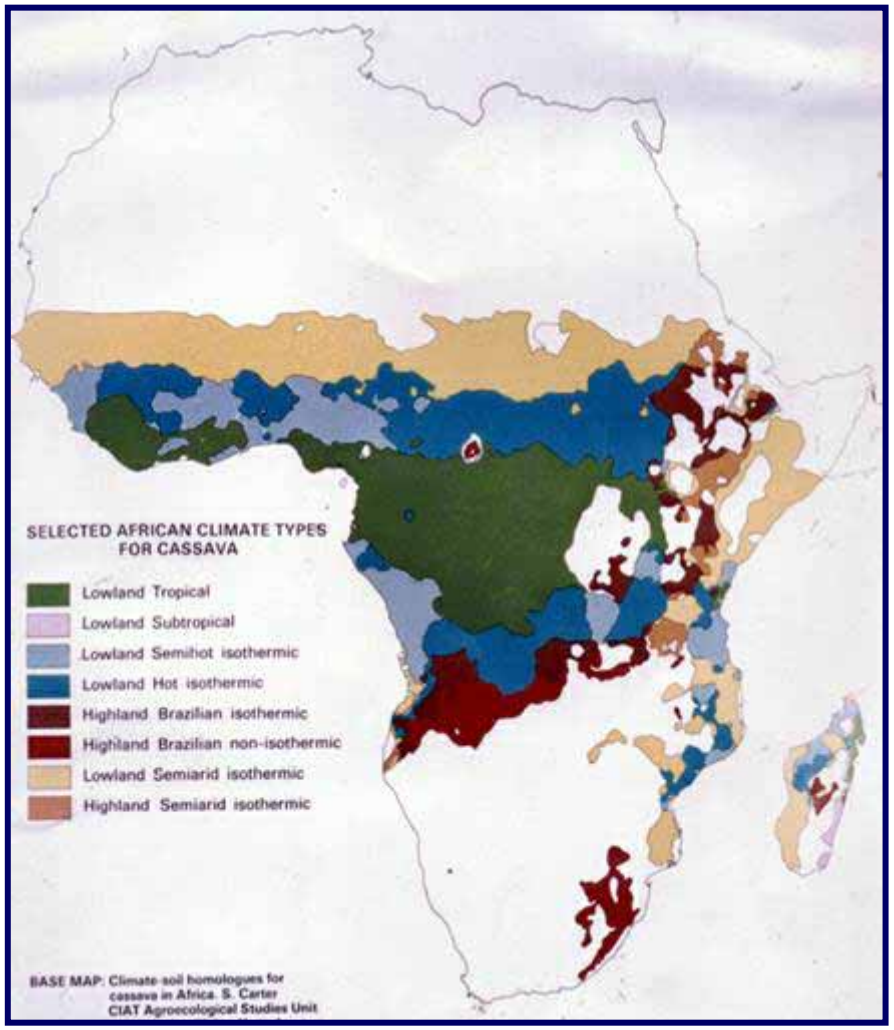
- **75 morphological and agronomic descriptors**
  - **~ 100 % of Brazilian germplasm characterized (35 descriptors)**
  - **9 stable morphological caracteres to estimated the number of duplicates**
  - **~ 30 % of duplicates**

The application of morphological descriptors has resulted in a non-anatomical model for characterization of cassava genotypes

Sites where cassava Brazilian germplasm have been evaluated




SELECTED BRAZILIAN CLIMATES SIMILAR TO AFRICAN CLIMATES FOR CASSAVA
Lowland Tropical
Lowland Subtropical
Lowland Semihot isothermic
Lowland Hot isothermic
Highland Brazilian isothermic
Highland Brazilian non-isothermic
Lowland Semiarid isothermic
Highland Semiarid isothermic


SELECTED AFRICAN CLIMATE TYPES FOR CASSAVA
Lowland Tropical
Lowland Subtropical
Lowland Semihot isothermic
Lowland Hot isothermic
Highland Brazilian isothermic
Highland Brazilian non-isothermic
Lowland Semiarid isothermic
Highland Semiarid isothermic
BASE MAP: Climate-soil homologues for cassava in Africa. S. Carter
CIAT Agroecological Studies Unit

Selection of Contrasting Varieties

40 Varieties Selected:

28 drought tolerants: selected by

Embrapa: 17

CIAT: 11

} **Embrapa and CIAT: 5**

12 drought susceptibles: selected by

Embrapa: 8

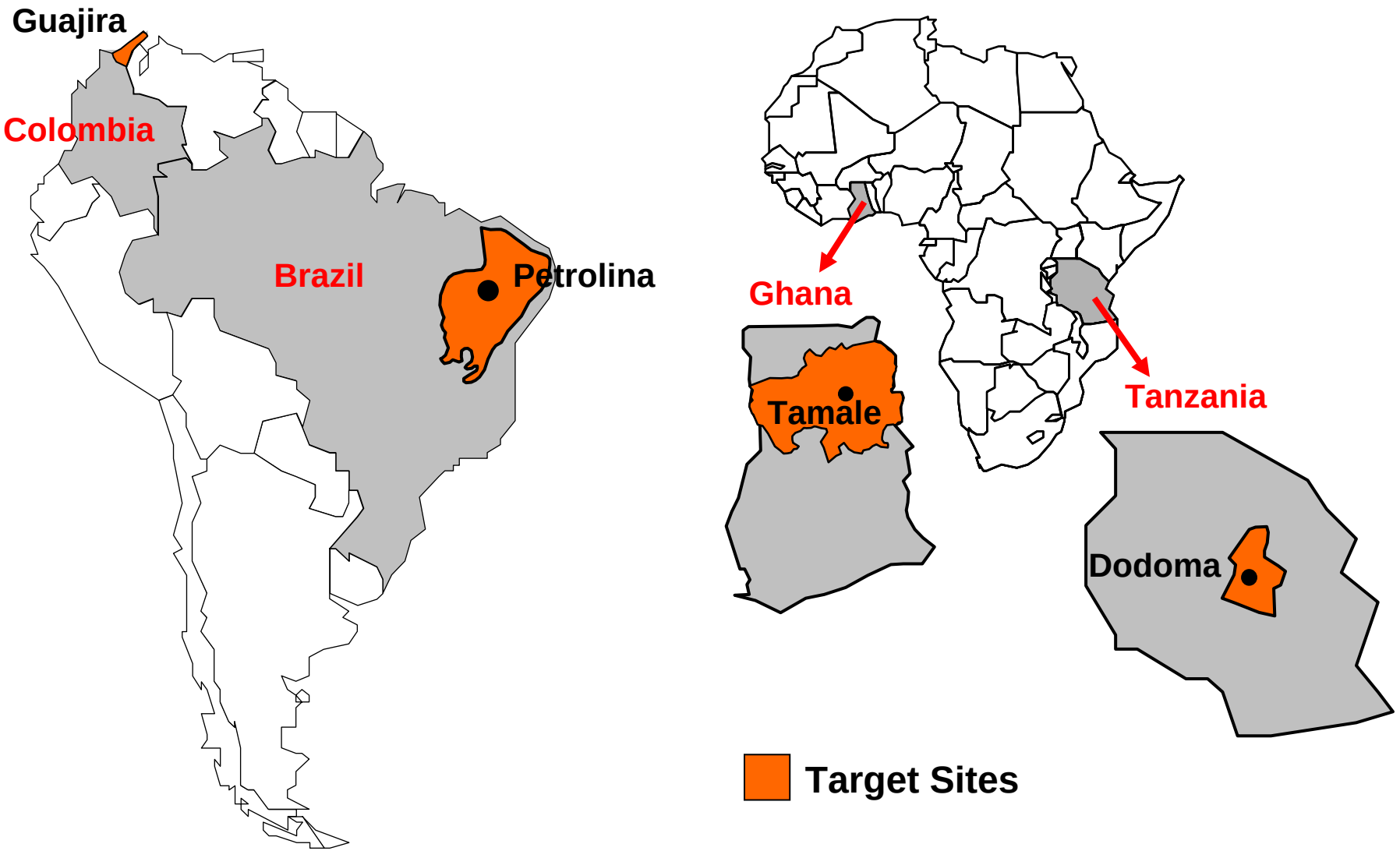
CIAT: 4

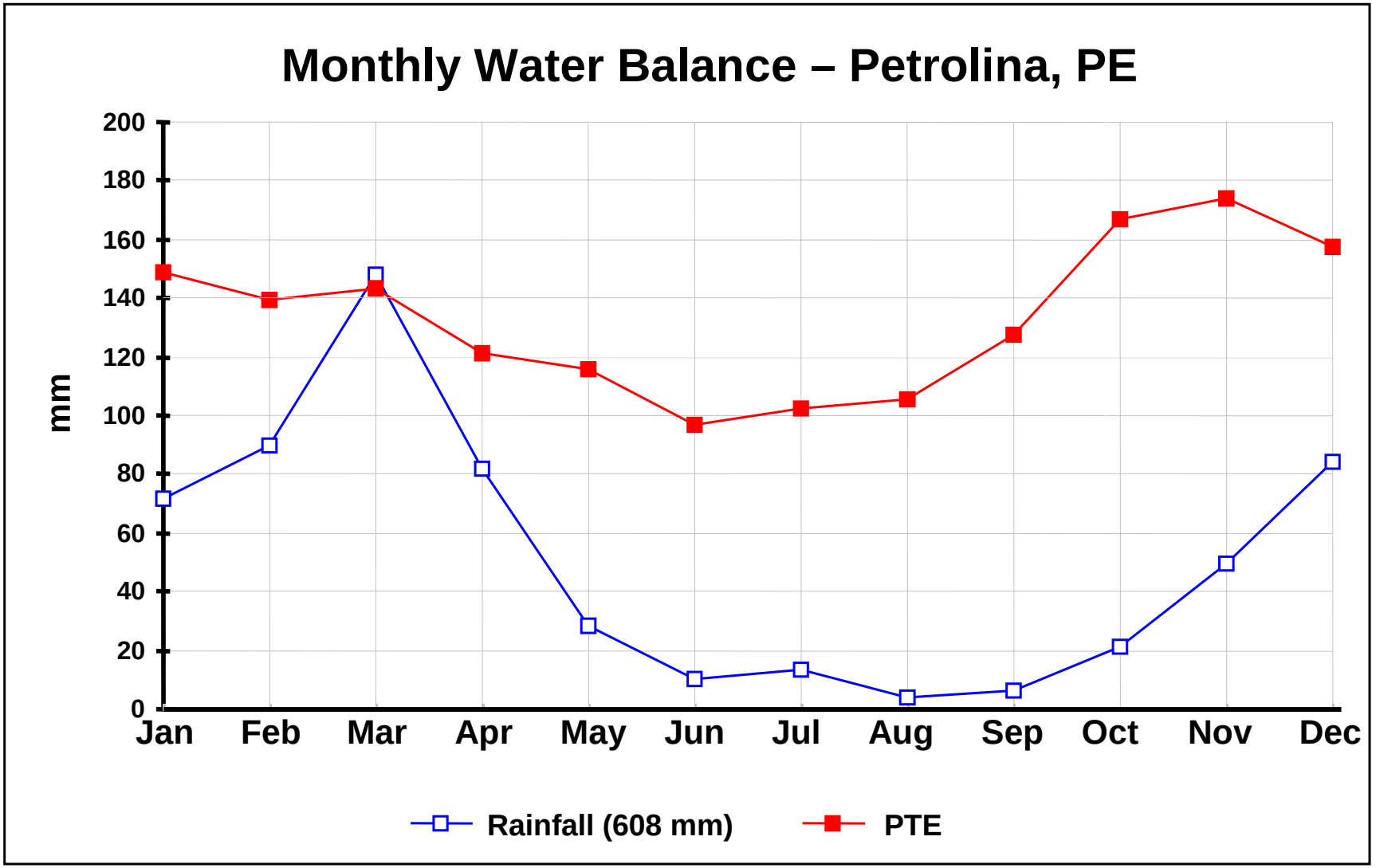
Activities / Methods

2. Identification of cassava genotypes with wide diversity for drought tolerance traits

- *Crosses 20 Tol vs 10 Sus; and self of Tol*
- *Selection of the 4 best parentals combinations and progenies evaluation*
- *200 seeds of each cross germinated in vitro e multiplied to produce 40 copies → shared to Brazil, Colombia, Ghana e Tanzania*
- *At each local: in vitro multiplication (rapid propagation) to evaluate the segregating populations*
- *In the segregating populations and parentals: evaluation of water deficit effects*
- *Identification of genotypes with good drought tolerance → incorporate to breeding program or directly used by farmers*

Locations for evaluation




Monthly Water Balance – Petrolina, PE
mm
200
180
160
140
120
100
80
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Rainfall (608 mm)
PTE

Activities / Methods

3. Identification of molecular markers associated with drought tolerance genes

- *4 segregating populations (F1); progenies from selfing (S1) e parentals: evaluated in the replicated trials*
- *Segregant parentals lines → genotyped with >600 markers from cassava genetic map*
- *Polymophic markers evaluated in the (F1 e S1)*
- *Phenotypic and genotypic data analyzed to identify involved genes*
- *Candidate genes mapped*
- *Identification of associations between markers and QTL for drought*

Atividades / Metodologia

4. Assessment of the effect of the leaf retention gene for improving drought tolerance

- **ETH-Zurich → transgenic cassava expressing ipt gene**
- ***7 transgenic lines from clone (TMS 60444) → 2 lines with significant reduction of senescence***
- ***Transformed and non-transformed plants → evaluated in the field and greenhouse (Colombia) → to analyze the effect of transformation on drought tolerance attributes.***


Foto: A. Alves


Foto: A. Alves

Atividades / Metodologia

5. Building capacity and strengthening partnership among International and National institutions involved with breeding programs for drought tolerance

- ***Training of NARS scientists from Brazil, Ghana and Tanzania***

- ***Technical backstopping from CIAT, CU and IITA to Embrapa and African NARS partners on phenotypic screening, markers analysis and data management***

Institutions involved

- **Embrapa Cassava & Tropical Fruits** (Project's coordenation)
  Alfredo A. C. Alves, PI

- **CIAT, Centro Internacional de Agricultura Tropical, Colombia**
  Martin Fregene, CoPI
  Hernán Ceballos

- **IITA, International Institute of Tropical Agriculture, Nigeria**
  Morag Ferguson, CoPI
  Edward Kanju
  Jonathan Mkumbira

- **SARI, Savannah Agriculture Research Institute, Ghana**
  Cecil Osei

- **ARI, Agriculture Research Institute, Tanzania**
  Geoffrey Mkamilo

- **Cornell University, USA**
  Tim Setter, CoPI

Thank you !

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http://www.cnpmf.embrapa.br

Water use efficiency (WUE)

Species	Single leaf *µmol CO_2 per mmol H_2O*	Total biomass *g DW per kg water*	Economic yield *g DW per kg water*
CASSAVA	5.3	2.9	1.7 (HI 60%) *
SORGHUM	6.2	3.1	1.2 (HI 40%)
BEAN	3.5	1.7	0.7 (HI 40%)
Cassava/sorghum (%)	85	94	140
Cassava/bean (%)	150	170	240

*** HI: Harvest index = (dry grain or dry root) / (total dry weight) x 100**

Source: El-Sharkawy and Cock (1986)