

Biological Nitrogen Fixation and Soil Management in Soybean: Successful cases in Brazil



Fonte: Eduara Ferreira



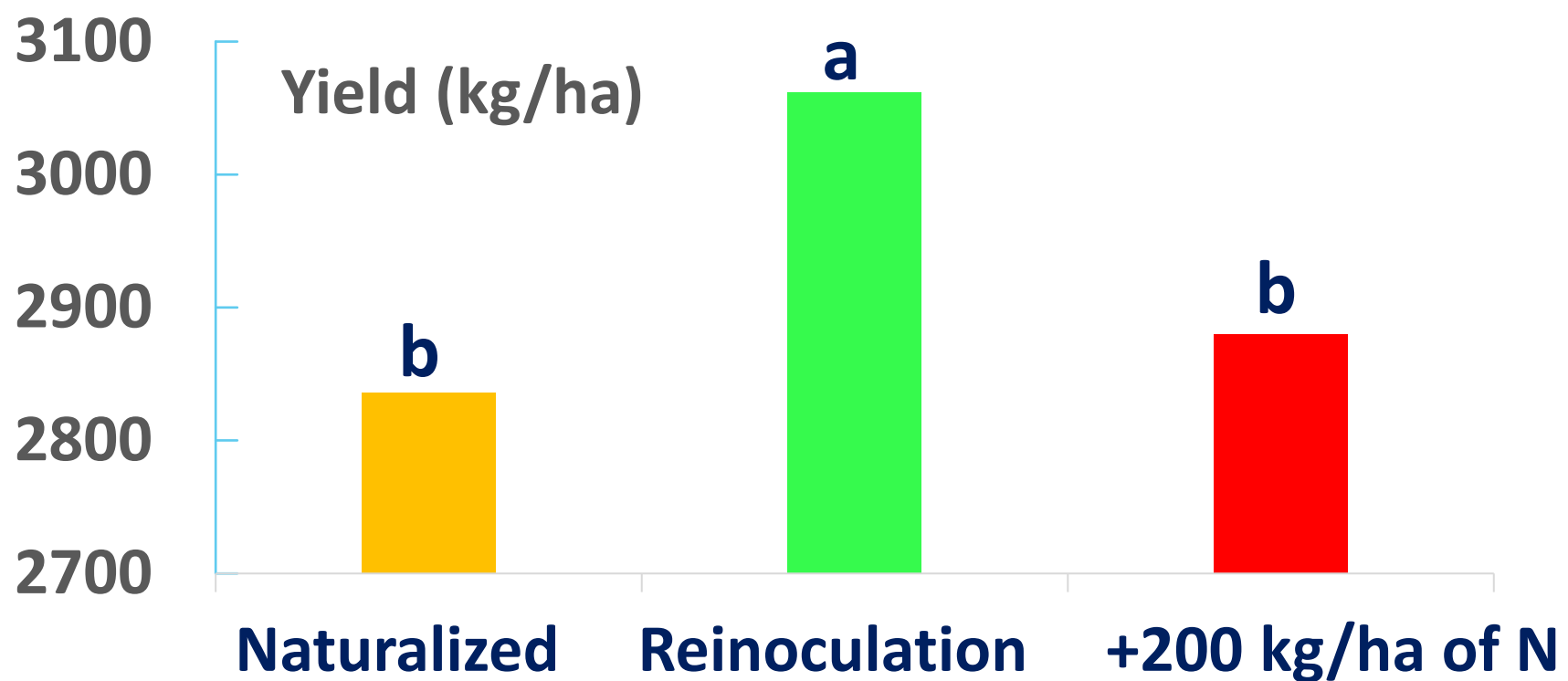
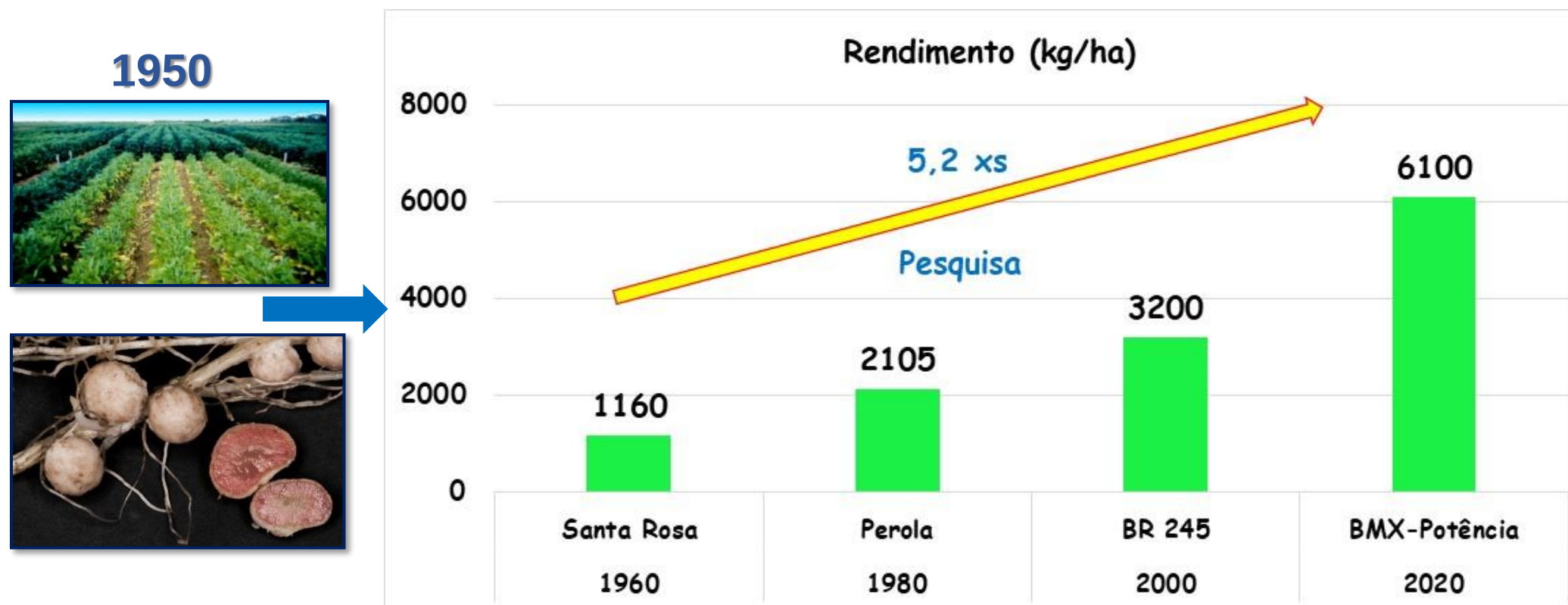
Marco Antonio Nogueira
Researcher at Embrapa Soybean, Londrina PR Brazil
Presentation to South African Visitors
September 17th, 2024

An overview on the Brazilian agriculture



- Cropped area: ~75 Mha;
- Pastures 165 Mha, ~ 30-40 Mha will be converted into crops in the next 20 years;
- >15 Mha were cropped under “agriculture-livestock-forest integration (iLPF in Portuguese)” by 2020, nowadays >17 Mha;
- In 2022, more than 15 Mha of maize were cultivated after soybean on the same area in the same year;
- Wheat: the last commodity to be dominated. Nowadays ~7 Mtons, to ~12 Mtons by 2030.

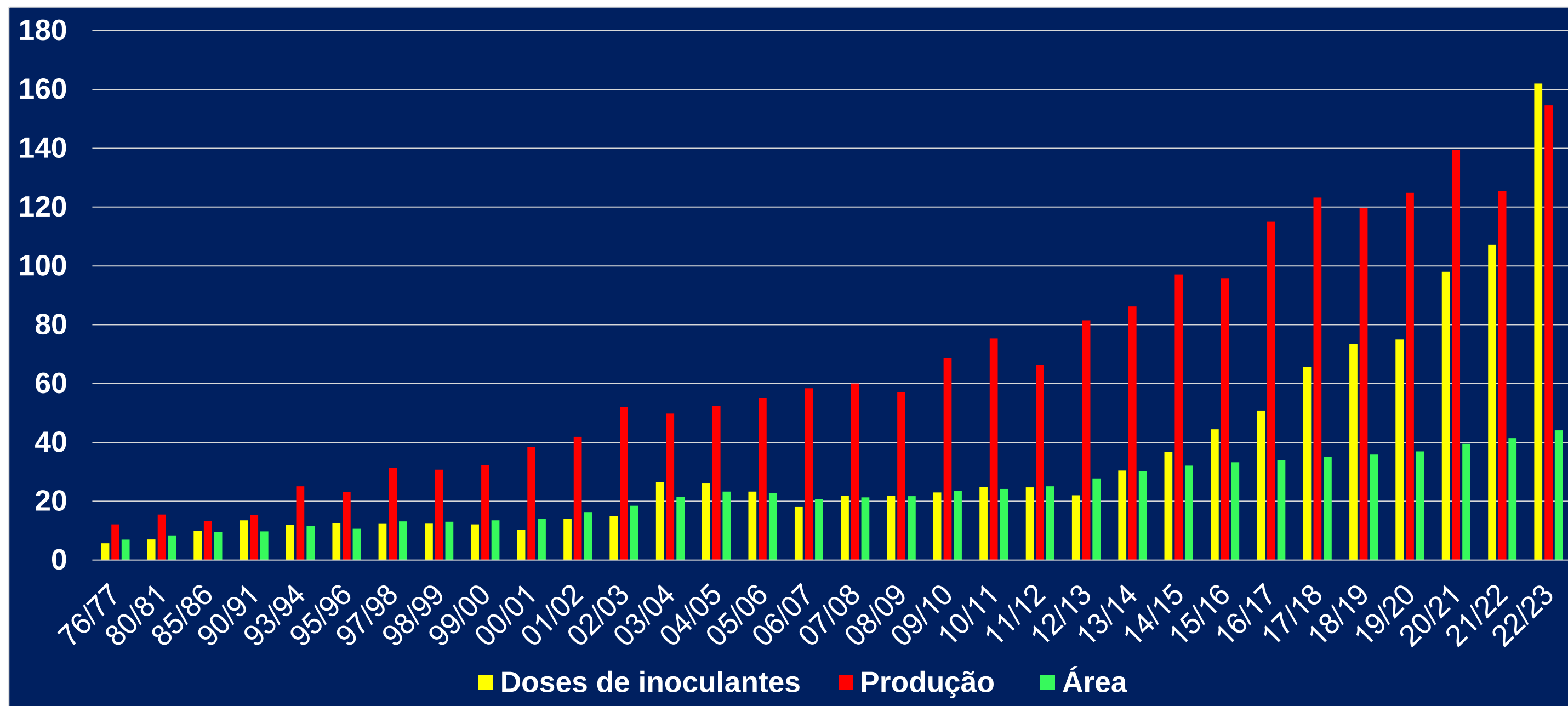
A successful case: soybean inoculation with *Bradyrhizobium* spp.



> 300 trials
 10^3 to 10^6 cells/g soil
+ 8% ($p < 0.05$)

A successful case: soybean inoculation with *Bradyrhizobium* spp.

Million (doses, tons or ha)

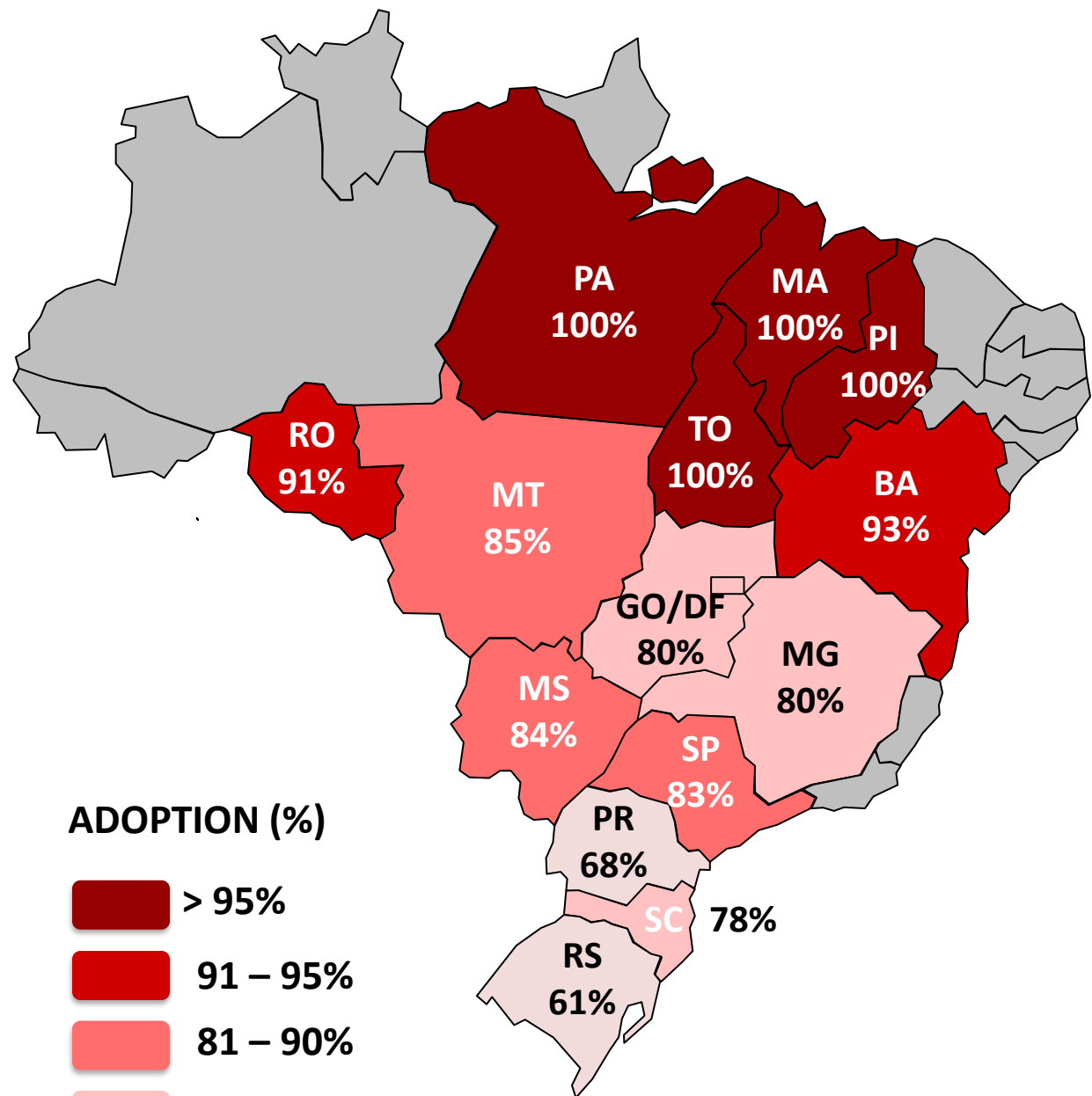


Source: Hungria & Nogueira (2022). Bioinsumos na cultura da soja; ANPIL

Soybean inoculation in Brazil, % of adoption

Cultivated Area (1,000 ha): 35.936

19/20

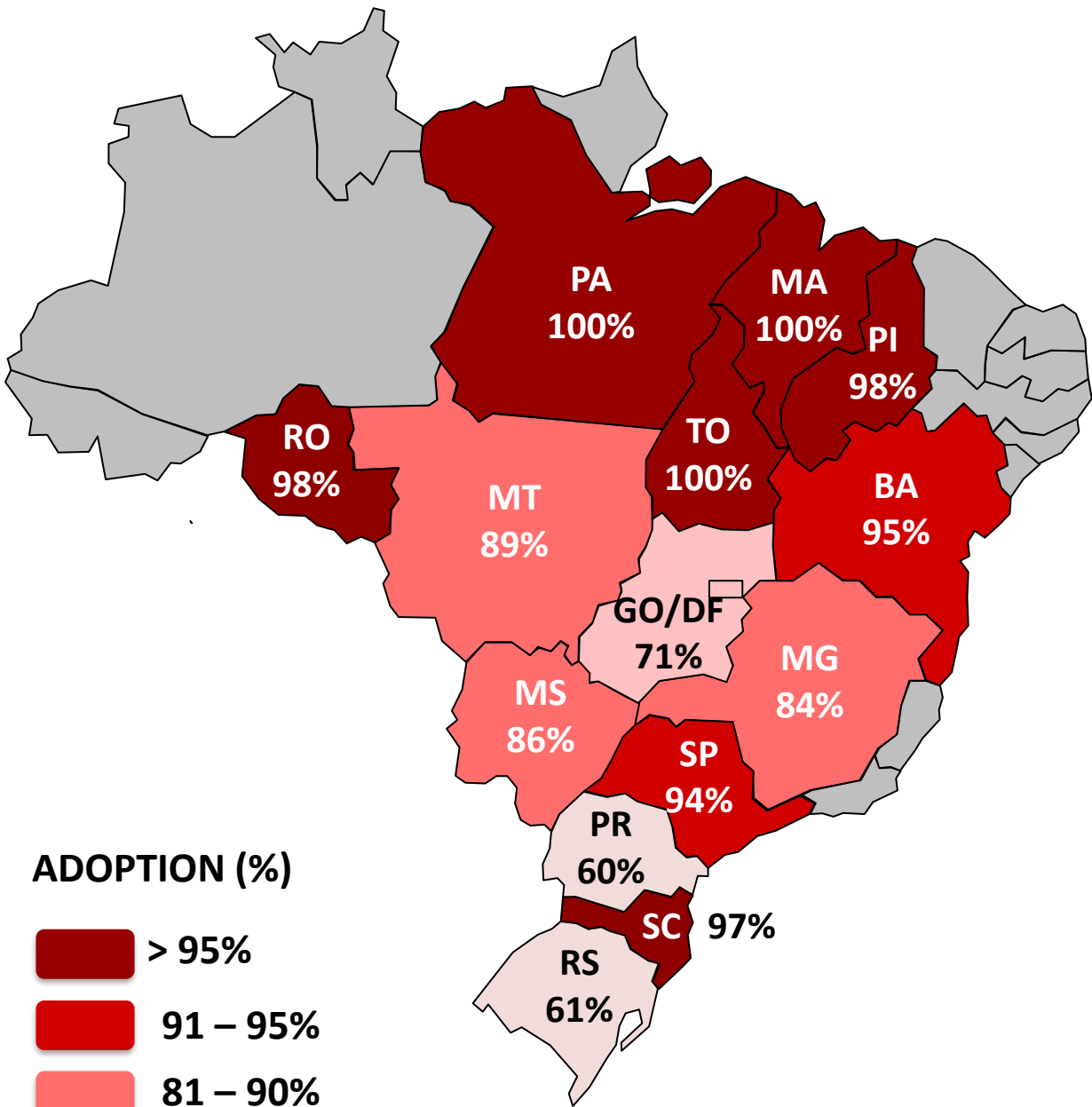


BR

79% ADOPTION

Cultivated Area (1,000 ha): 37.772

20/21

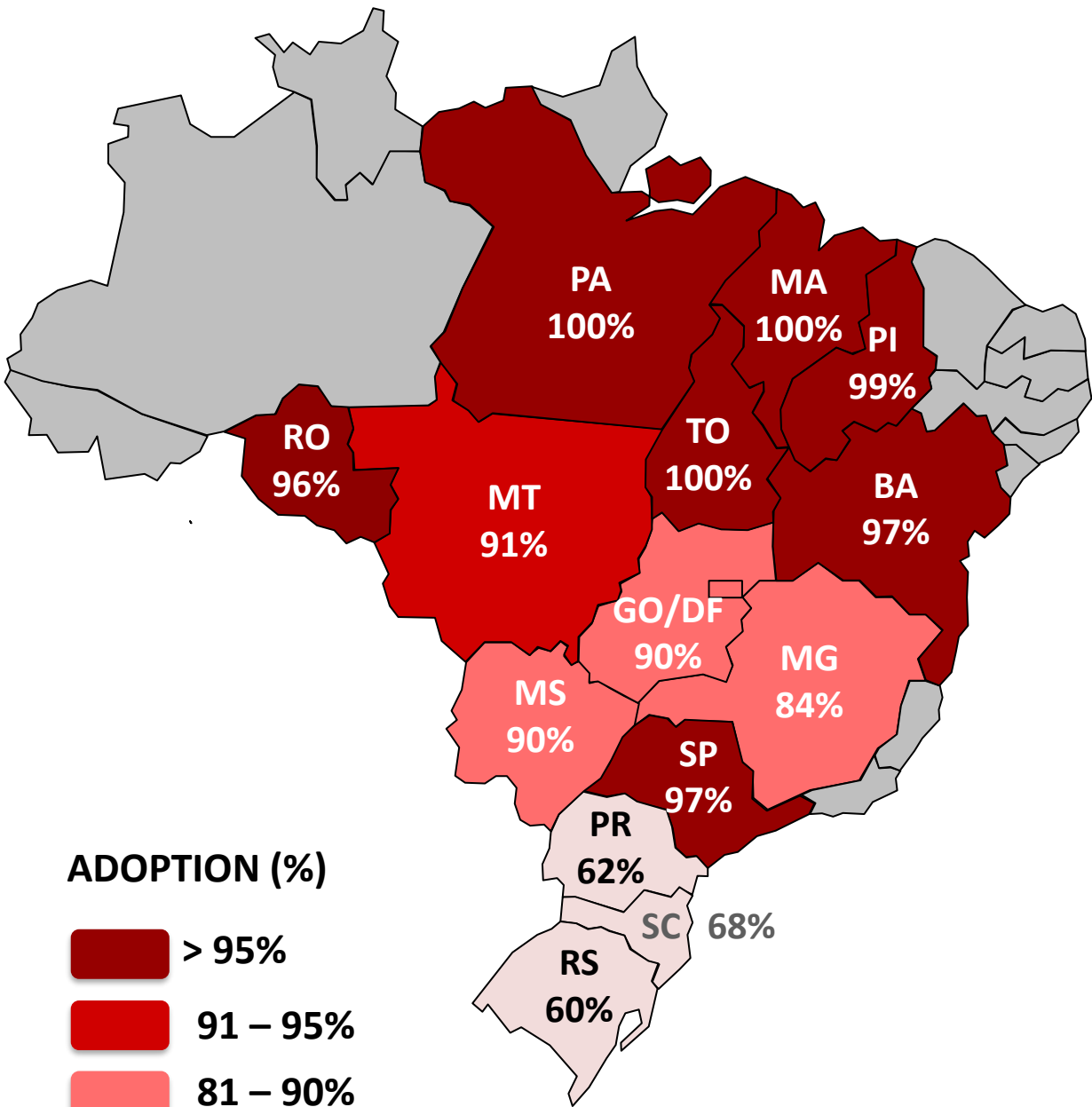


BR

80% ADOPTION

Cultivated Area (1,000 ha): 39.854

21/22



BR

82% ADOPTION

The numbers of BNF in Brazil

Considering only Soybean
(2019-2020)



~US\$ 15.2 billion/yr

~183 Mton of CO₂-eq. avoided

- ✓ One of the most successful cases of using microorganisms in agriculture;
- ✓ Advantages for the farmer and the environment.

Plant growth-promoting bacteria: *Azospirillum brasilense*

Azospirillum spp.

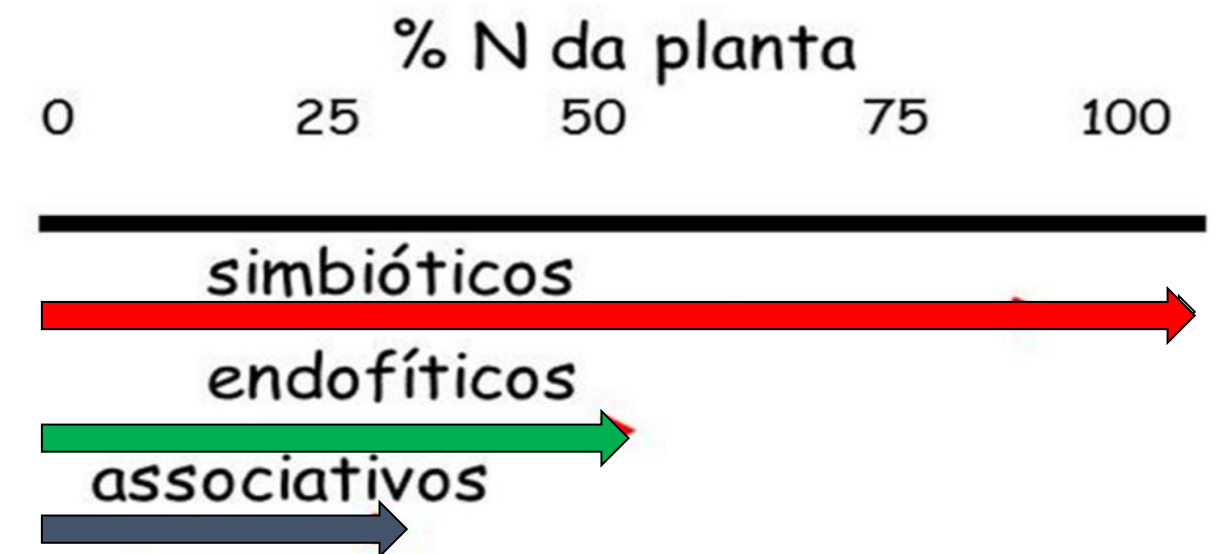
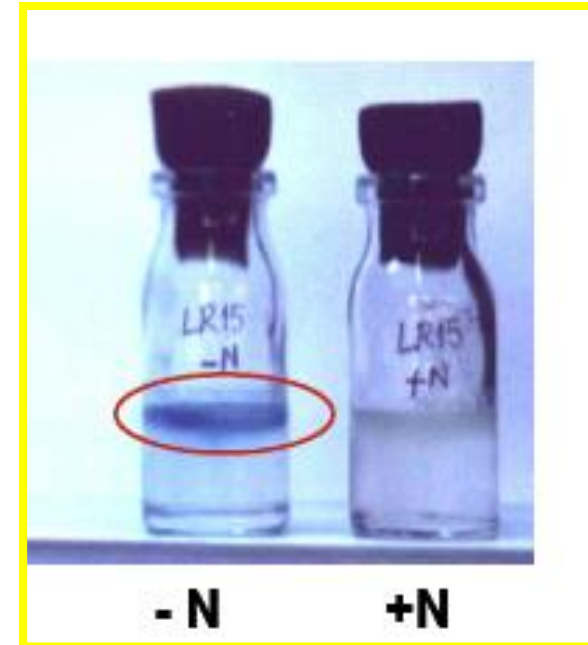


End of the 1970's

1) Biological Nitrogen Fixation



Johanna Döbereiner



2) Synthesis of phytormones



Yaacov Okon



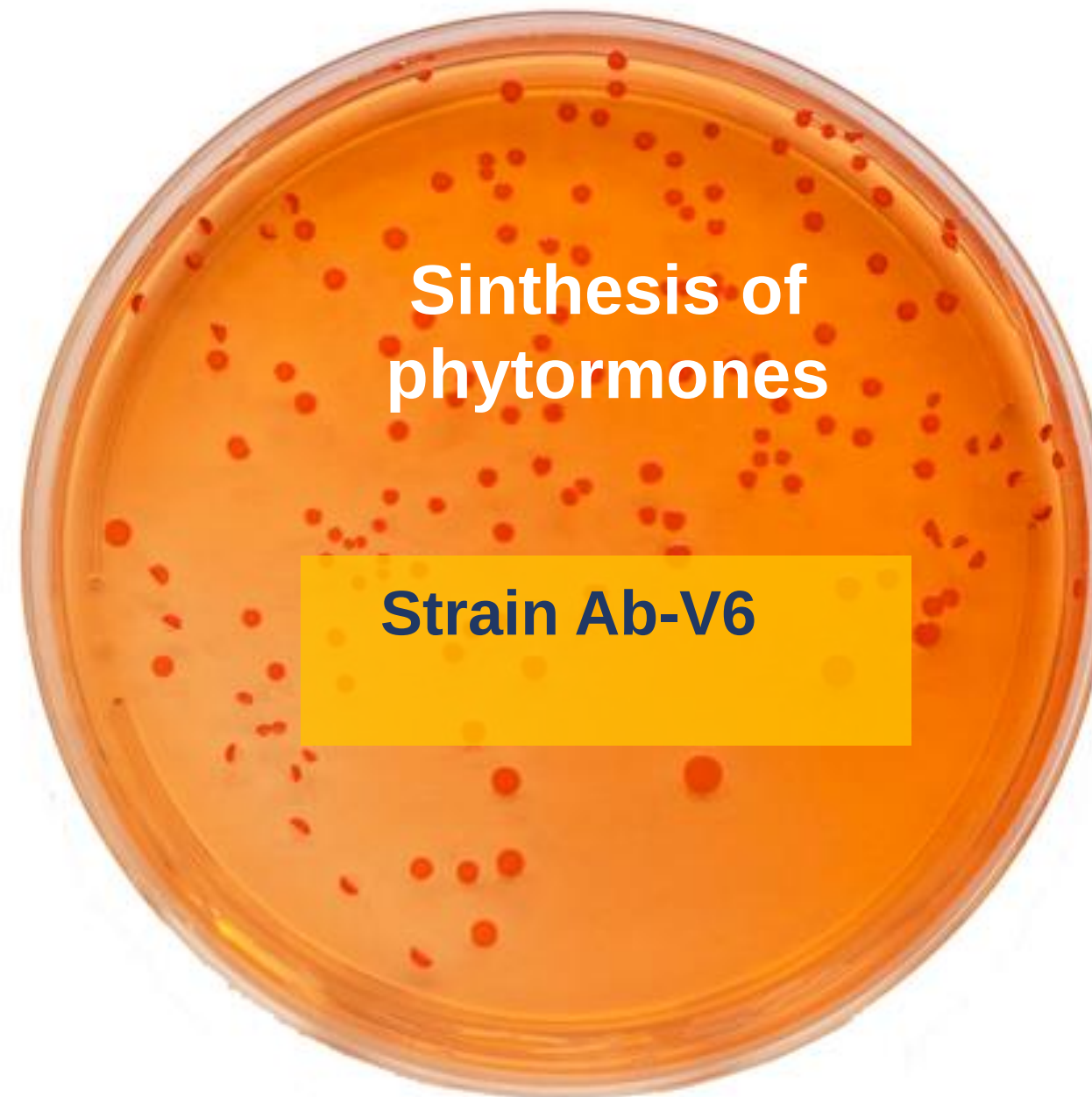
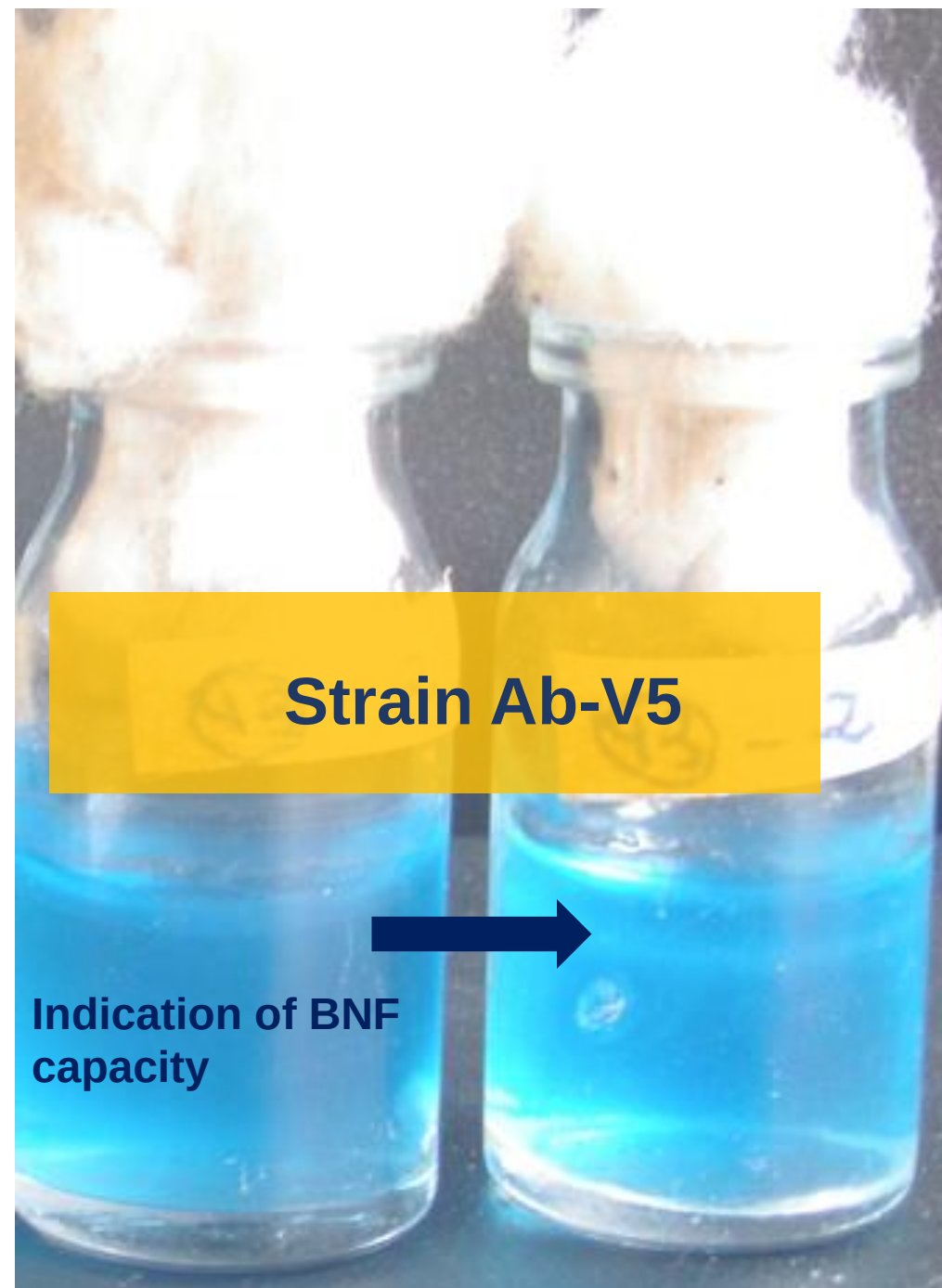
Non-inoculated



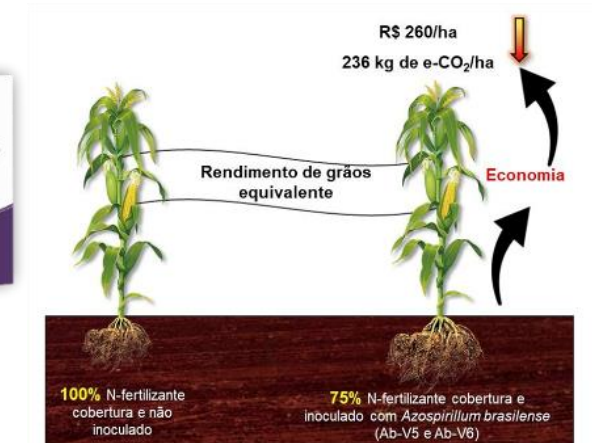
Inoculated



Strains Ab-V5 and Ab-V6 of *Azospirillum brasilense* promote growth of maize and wheat



Azospirillum registered as inoculant



2009

2014

2017

2021

2022

Maize
Wheat
Rice

Co-inoculation
of soybean and
common bean

Braquiarias
via seed
inoculation

Braquiárias via
sementes and
or foliar
inoculation

Reduction of N-
topdress in
maize by 25%



Documentos

ISSN 1516-781X
Janeiro, 2011 **325**

Inoculação com
Azospirillum brasilense:
inovação em rendimento
a baixo custo

TECNOLOGIA DE
COINOCULAÇÃO

RIZÓBIOS E
AZOSPIRILLUM
EM SOJA E
FEIJOEIRO

INOCULAÇÃO DE
BRAQUIÁRIAS COM
AZOSPIRILLUM

Inoculação
Multifuncional
para Pastagens
com Braquiárias

Inoculação do
milho com as
estirpes Ab-V5
e Ab-V6 de
***Azospirillum
brasilense***

Redução em 25% da
adubação nitrogenada
de cobertura



Co-inoculation *Bradyrhizobium*-*Azospirillum*

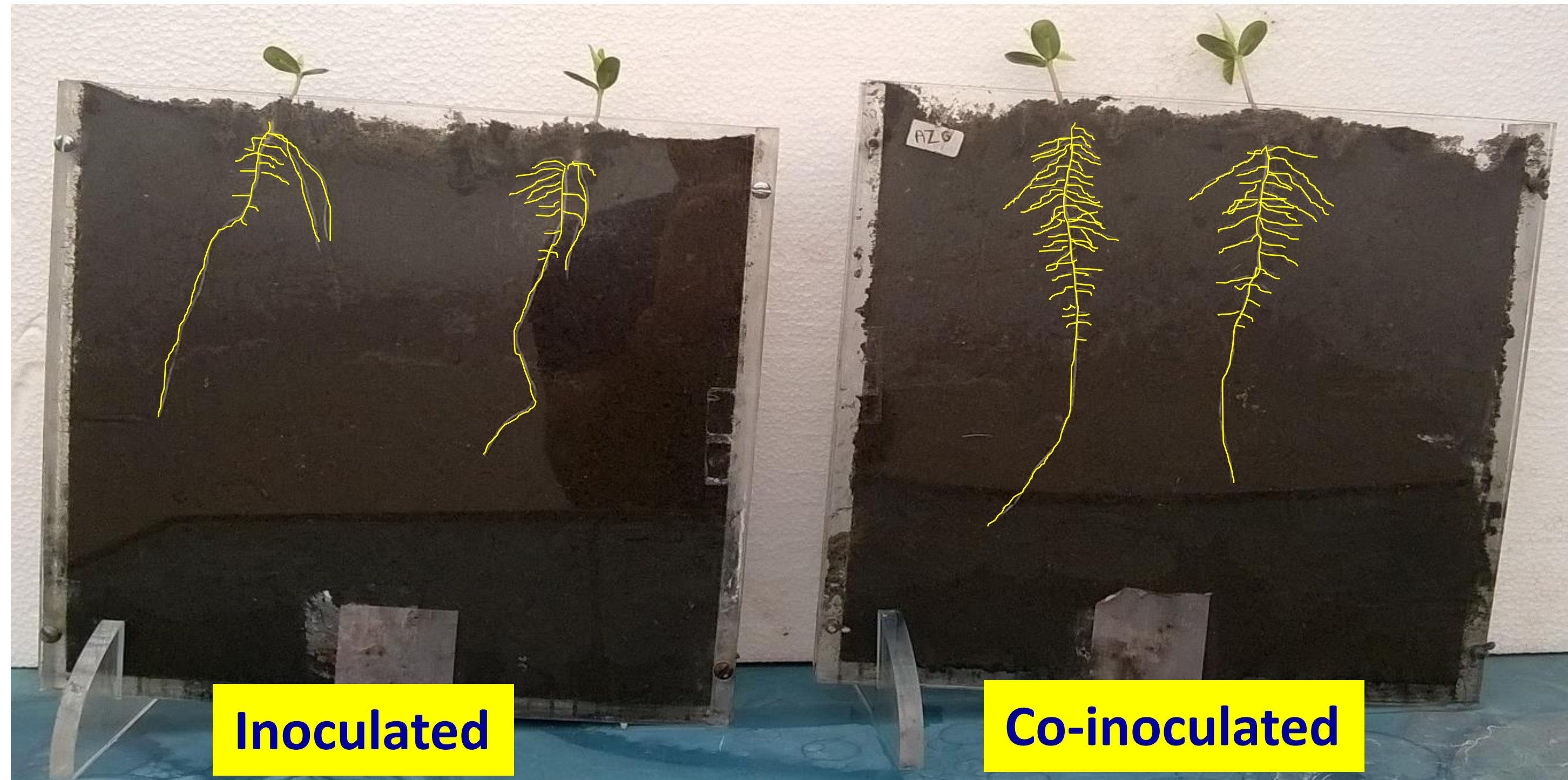


Foto: Embrapa Soja, 2017

Co-inoculation *Bradyrhizobium*-*Azospirillum*



% of yield increase

Soybean (4 trials)	≠ %
Single inoculation	8.4 *
Co-inoc. <i>Bradyrh</i> + <i>Azospirillum</i>	16.1 *

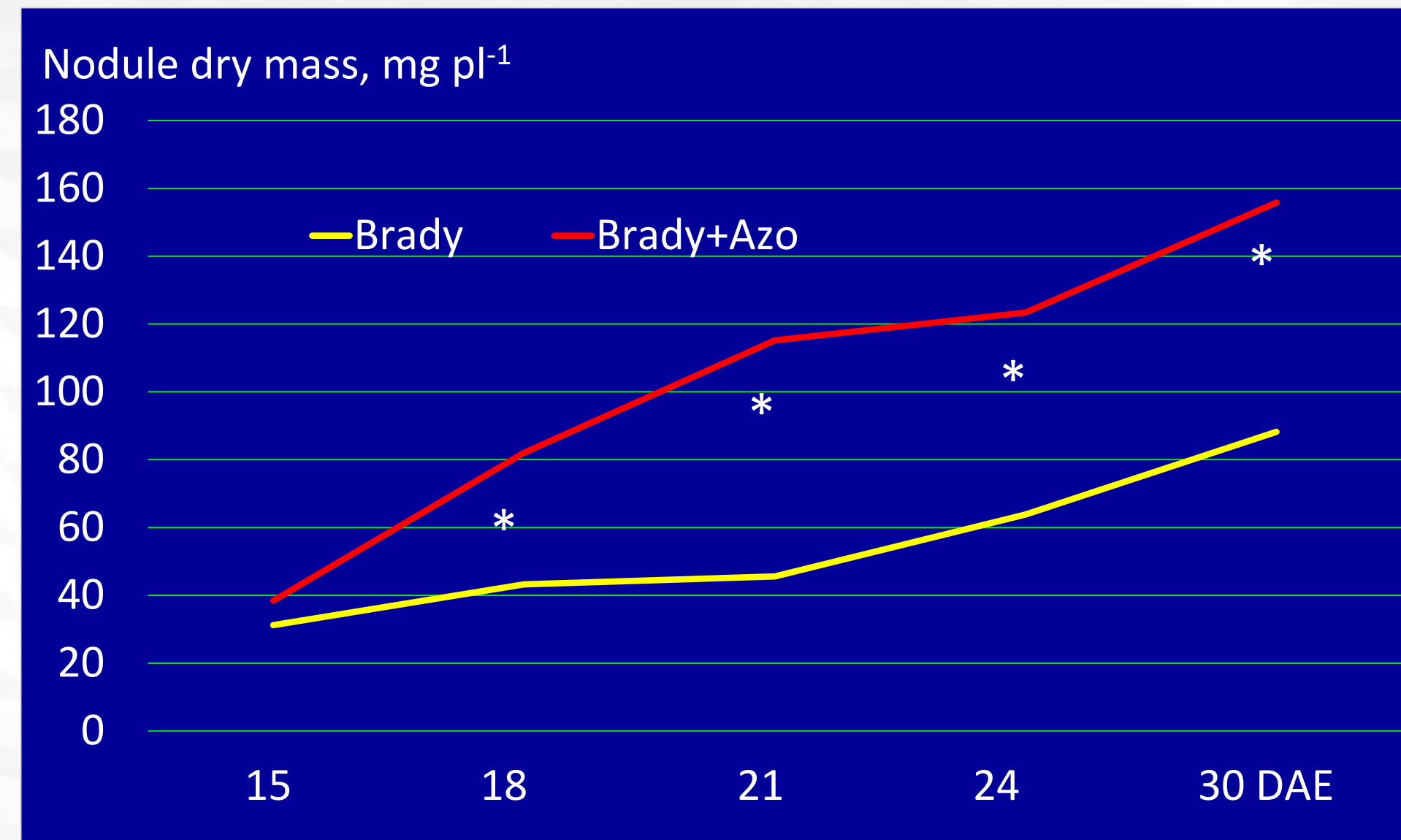
Hungria et al., Biol. Fert. Soils, 2013
Hungria et al., Amer. J. Plant Sci., 2015



TECNOLOGIA DE
COINOCULAÇÃO

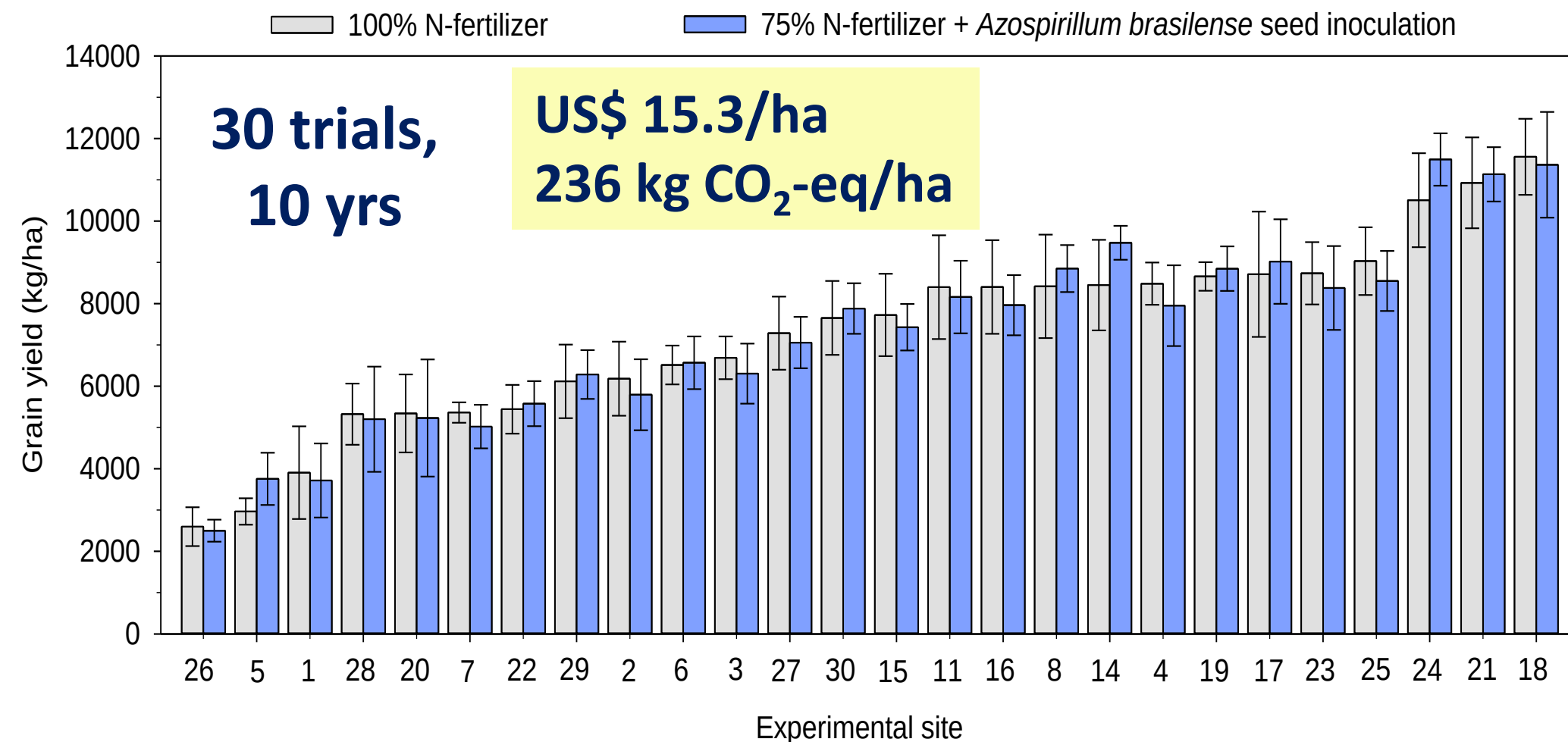
RIZÓBIOS E
AZOSPIRILLUM
EM SOJA E
FEIJOEIRO

Early nodulation, early BNF



Maize inoculation with *Azospirillum* saves 25% of top-dress N-fertilizer without yield loss

Azospirillum brasilense Ab-V5 + Ab-V6



Hungria et al. (2022), Agronomy Journal

- > Soil exploration
- > Efficiency of N use efficiency
- > Access to water



Foto: Embrapa Soja

Soybean co-inoculation with *Bradyrhizobium* and *Azospirillum*

Cultivated Area (1,000 ha): 35.936

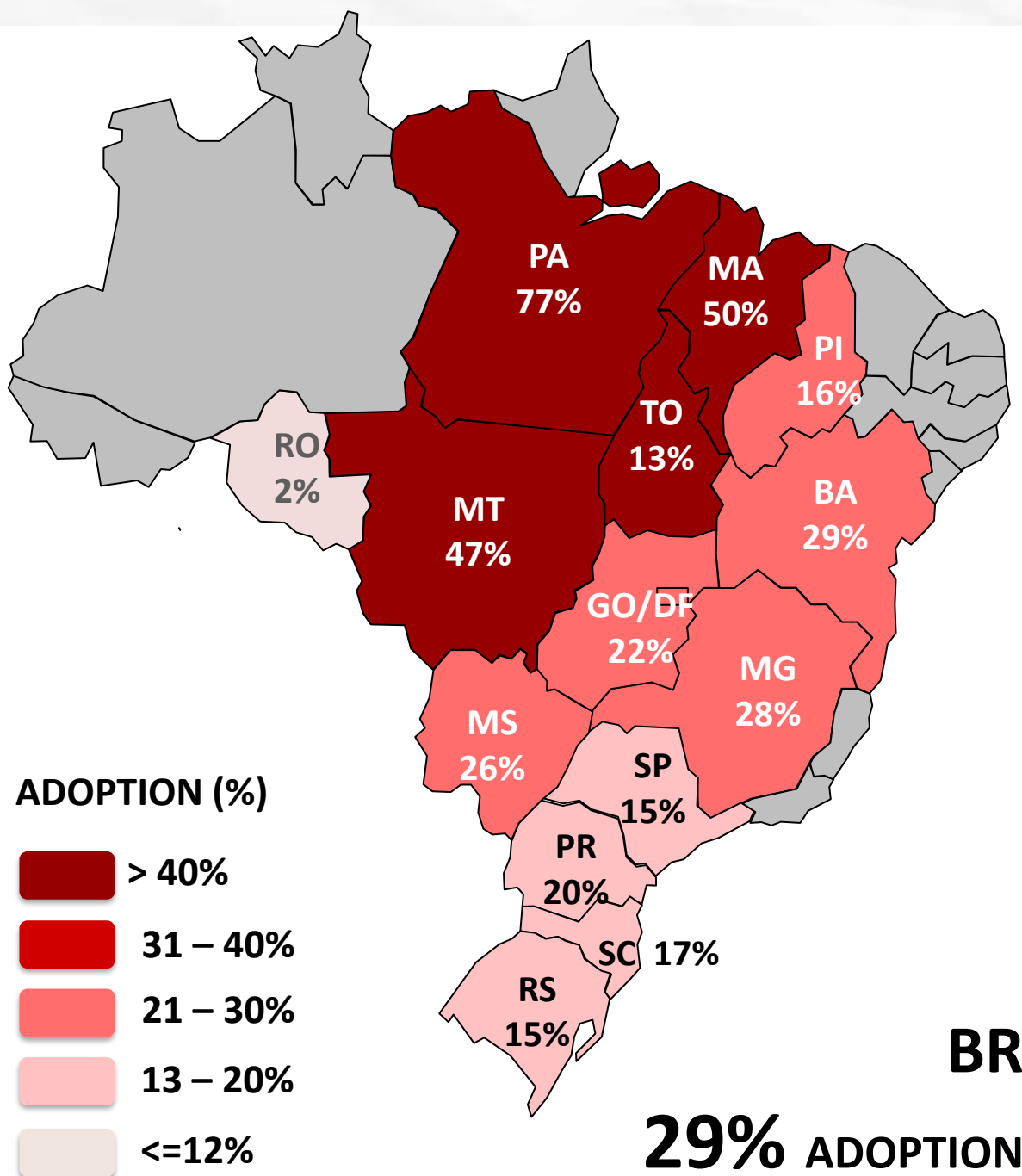
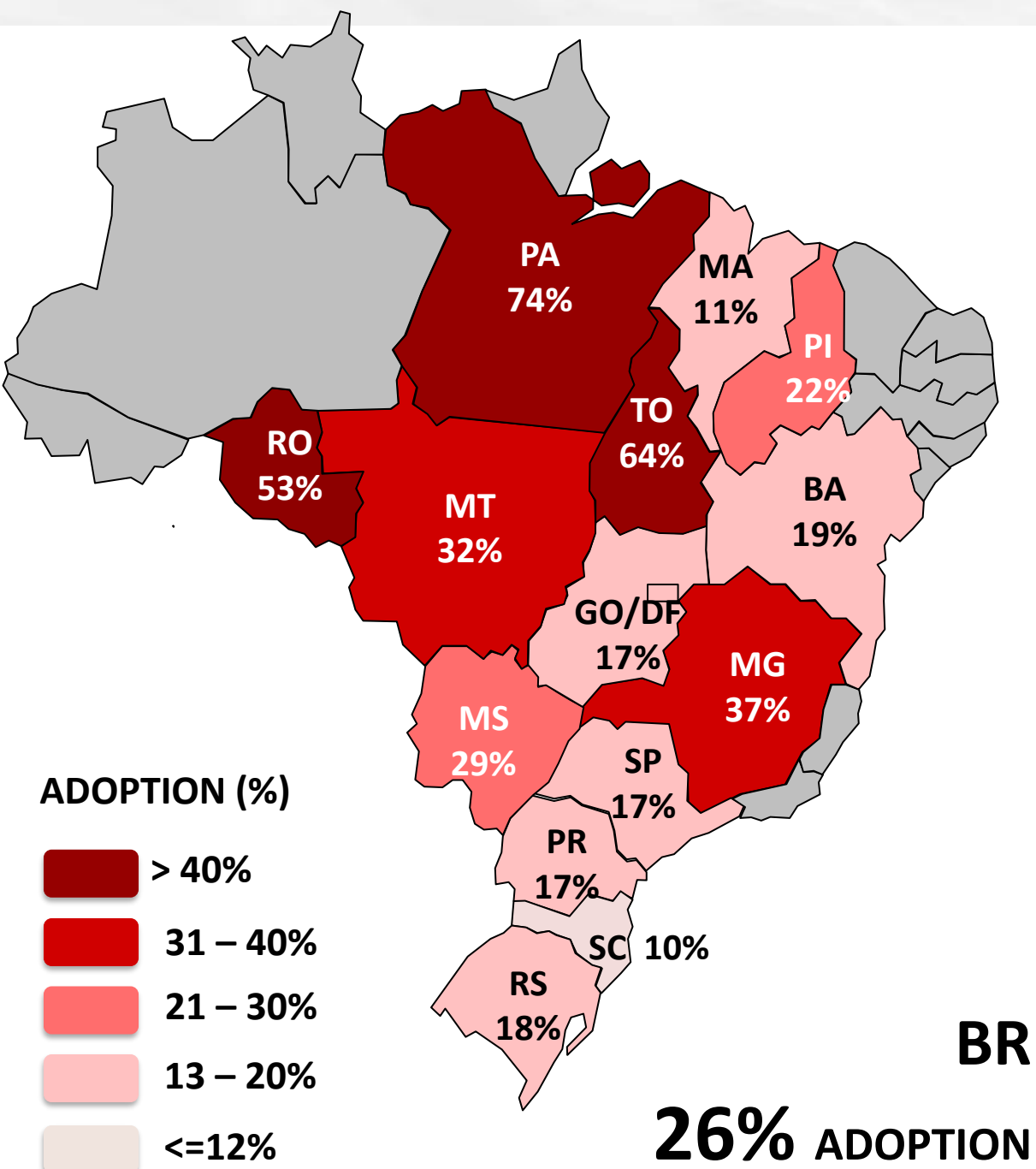
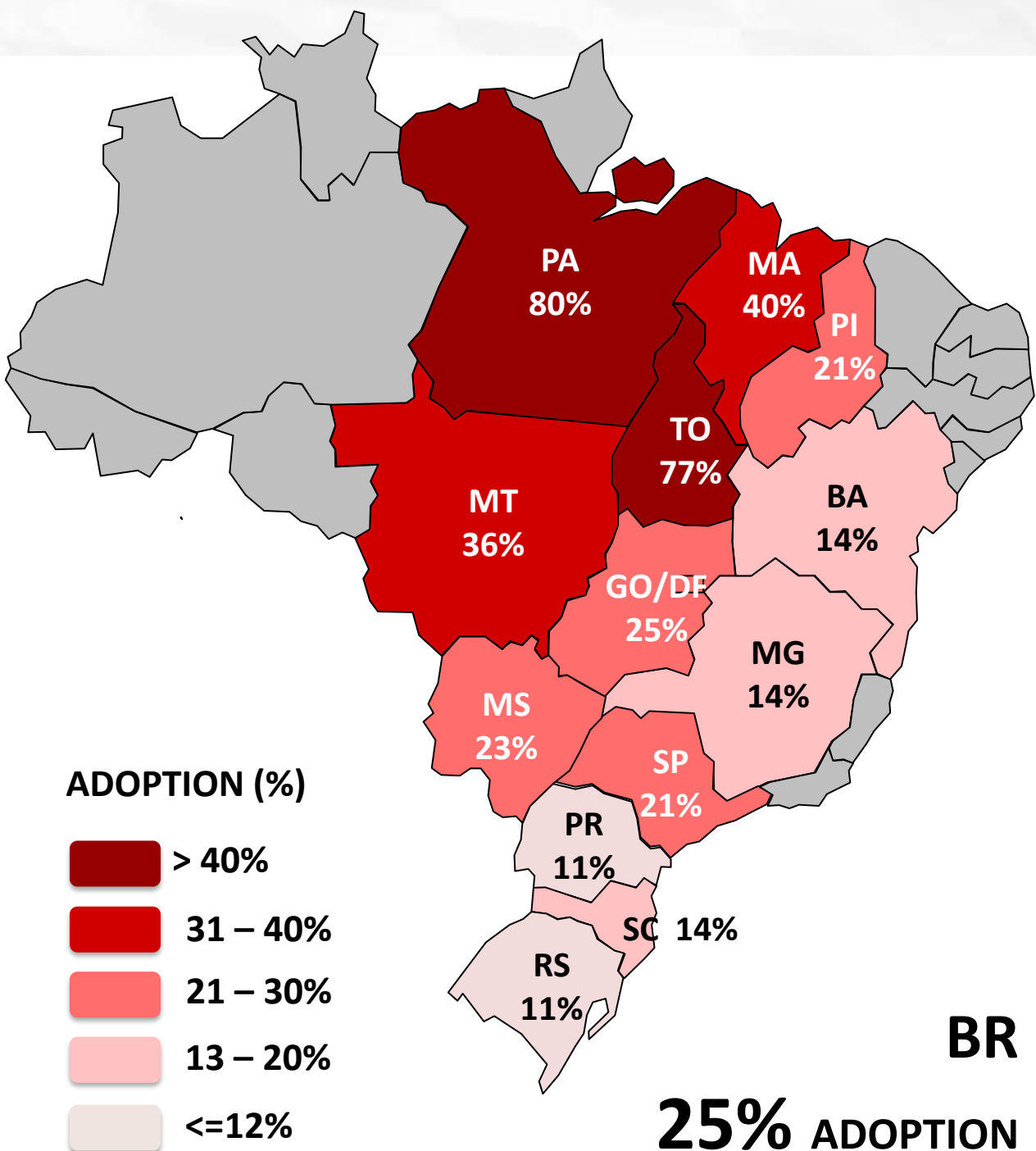
19/20

Cultivated Area (1,000 ha): 37.772

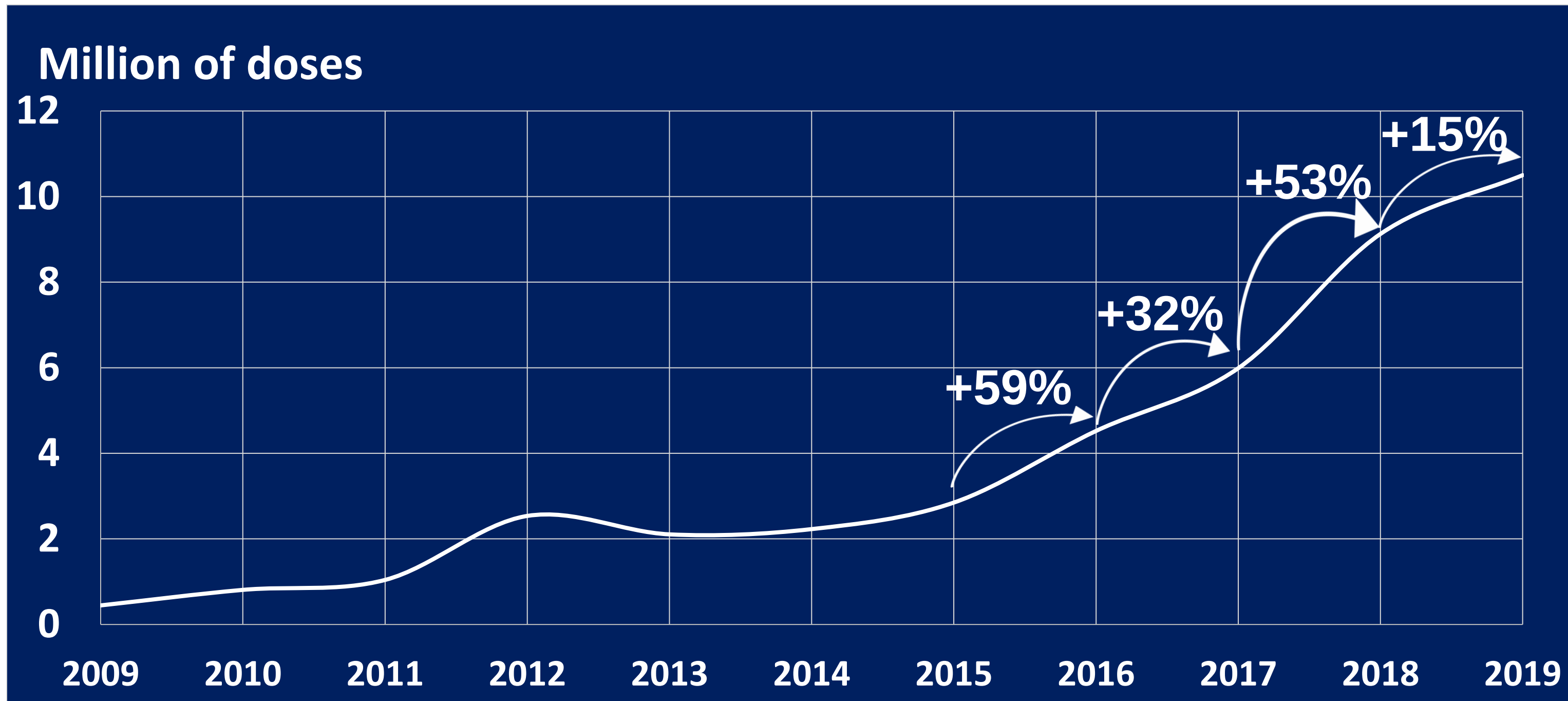
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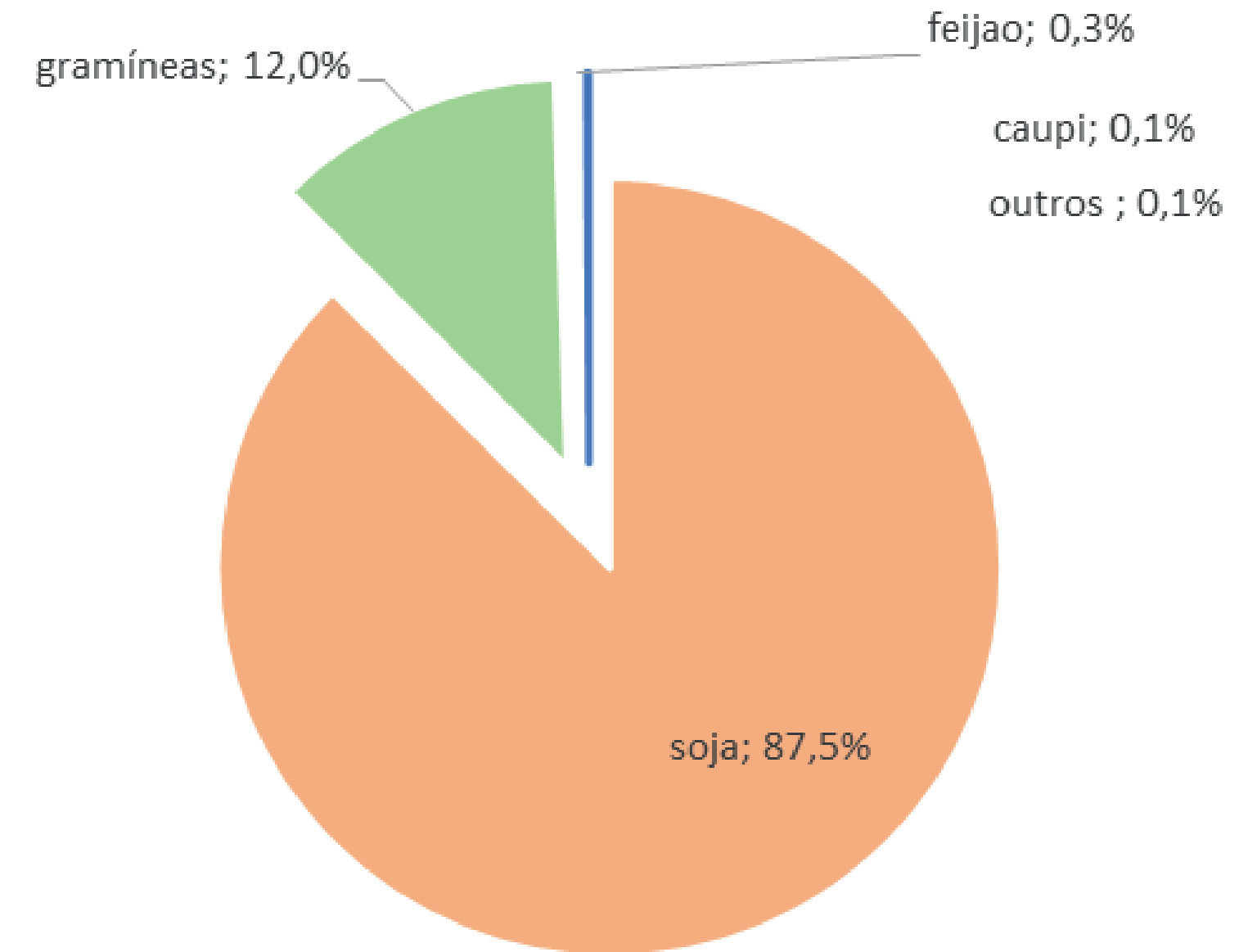
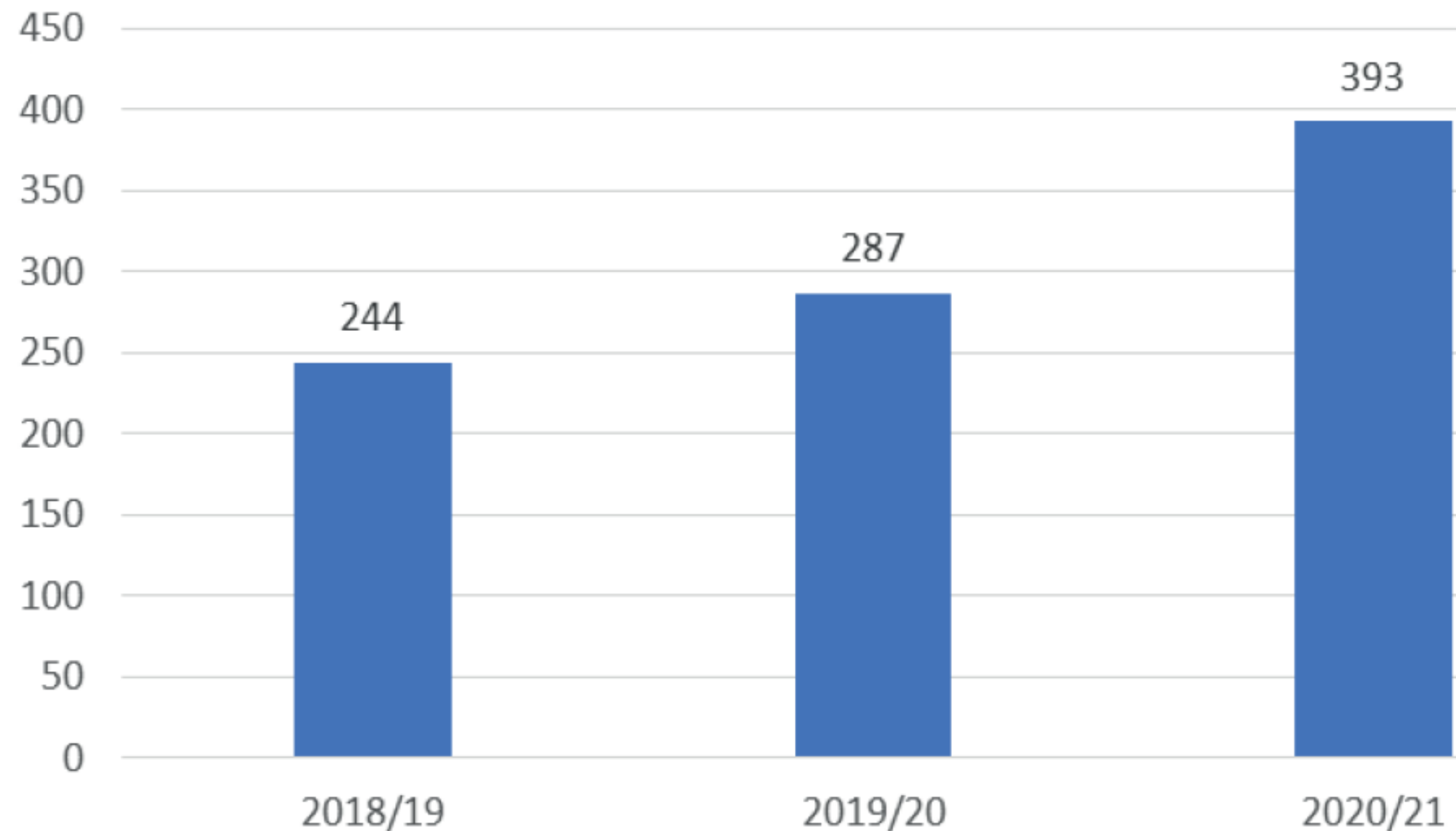


Increasing market of *Azospirillum*



Sources: Embrapa (2009-11) ANPII (2012-19)

Inoculants for biological nitrogen fixation and plant growth-promotion

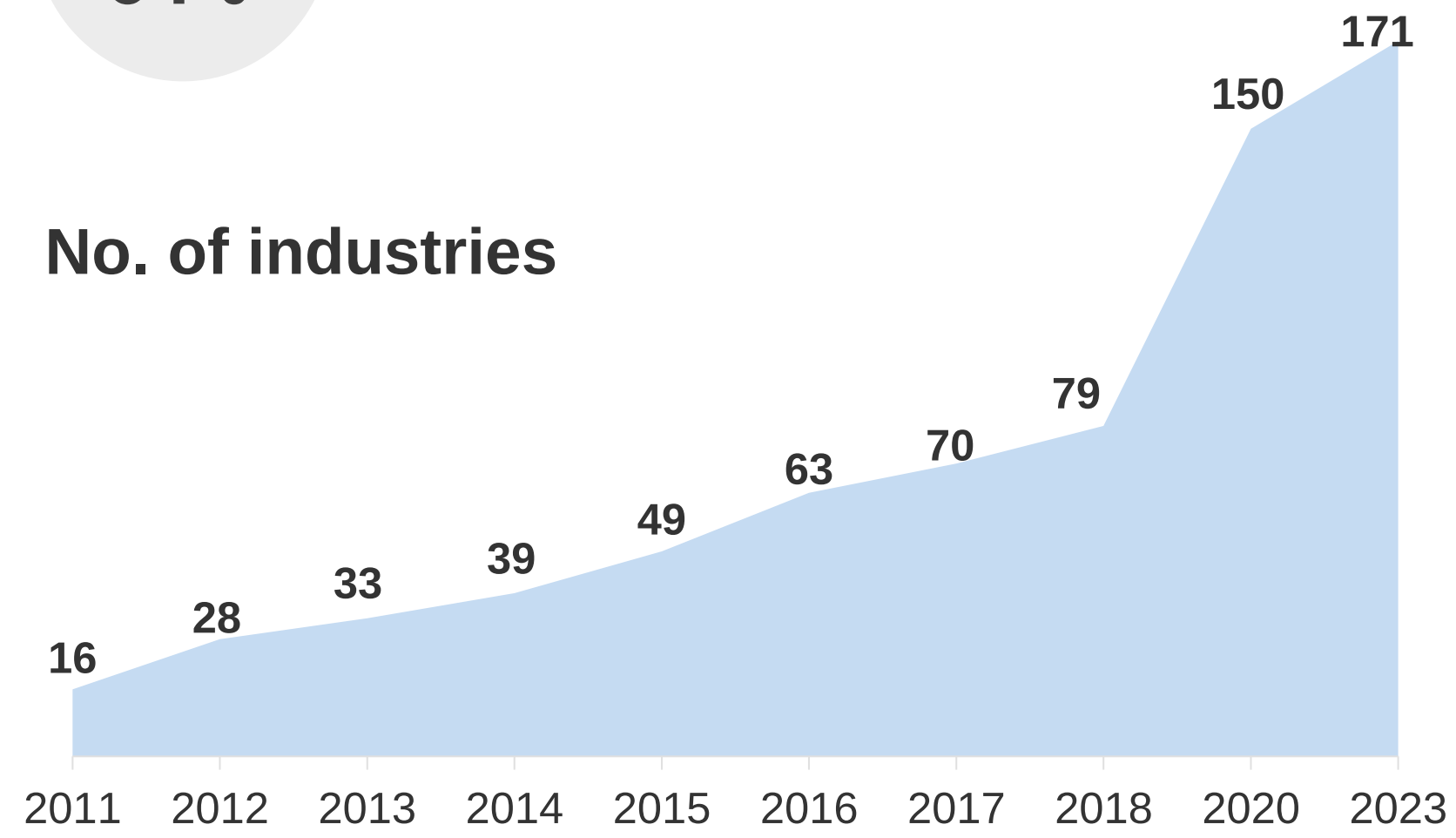
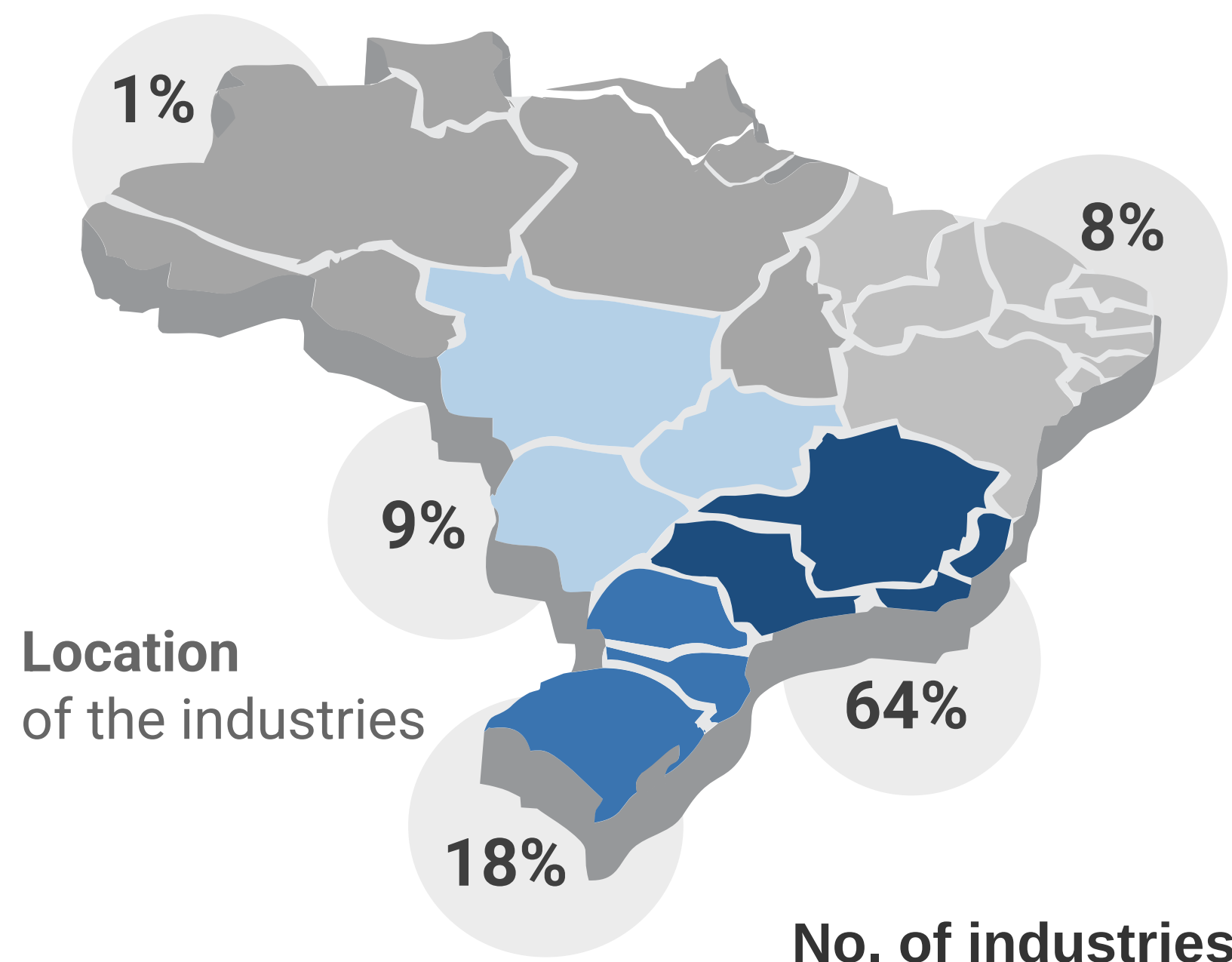


Brazilian market of inoculants, million BRL

Borsari & Vieira (2022). Bioinsumos na Cultura da Soja



Industries of Bio-inputs over the country

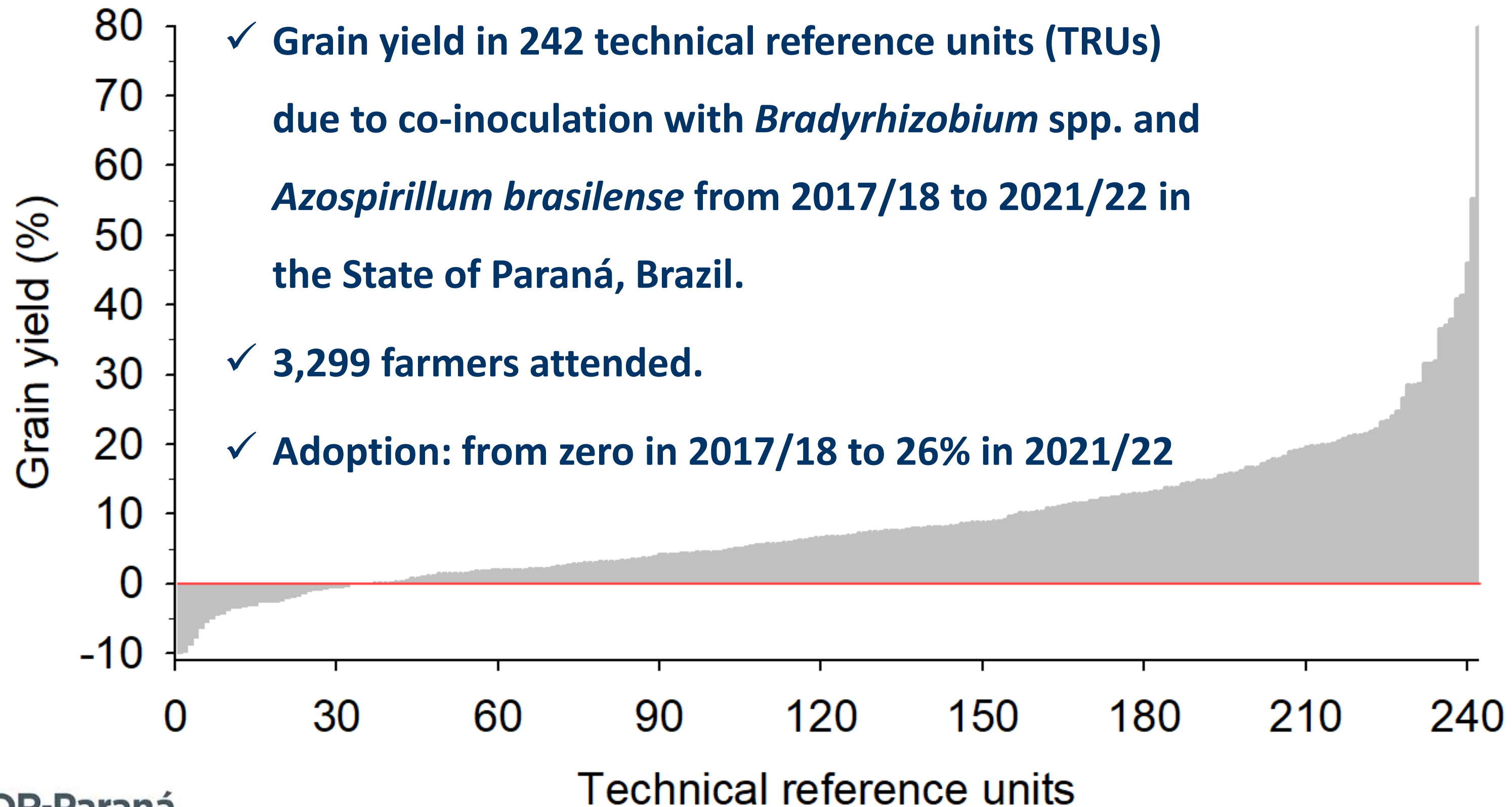


Northeast	
AL	4
BA	3
CE	2
PB	1
PE	2
RN	1
North	
TO	1
Central West	
DF	2
GO	5
MT	10
Southeast	
RJ	2
SP	96
MG	11
South	
PR	17
RS	10
SC	4
Total	171

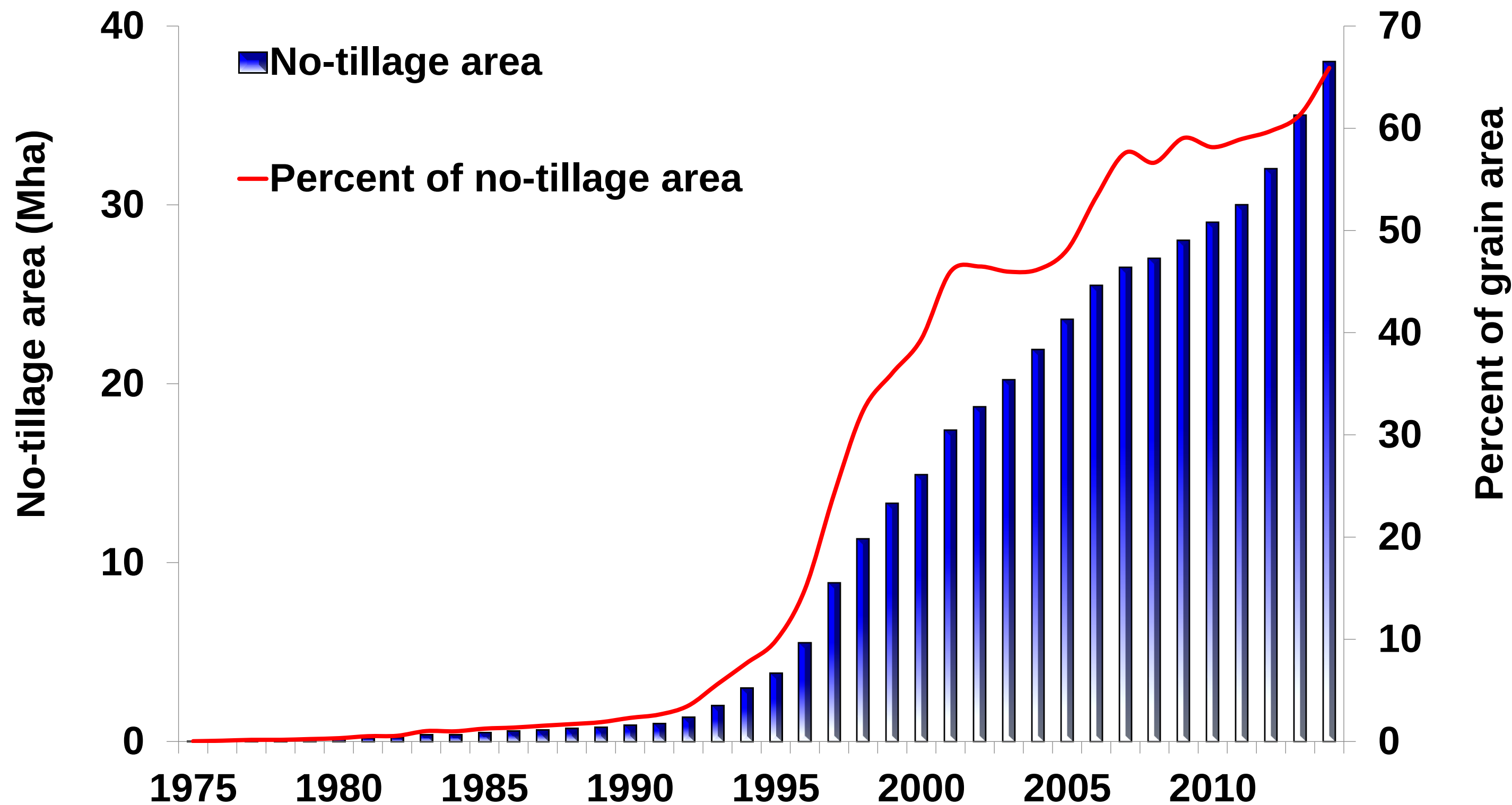
Source: MAPA

Slide kindly supplied by Dr. Jerri Zilli, Embrapa Agrobiology

Rural extension: taking technology closer to the farmer



No-tillage area and percent of the Brazilian grain area



No-tillage: soil conservation and C sink

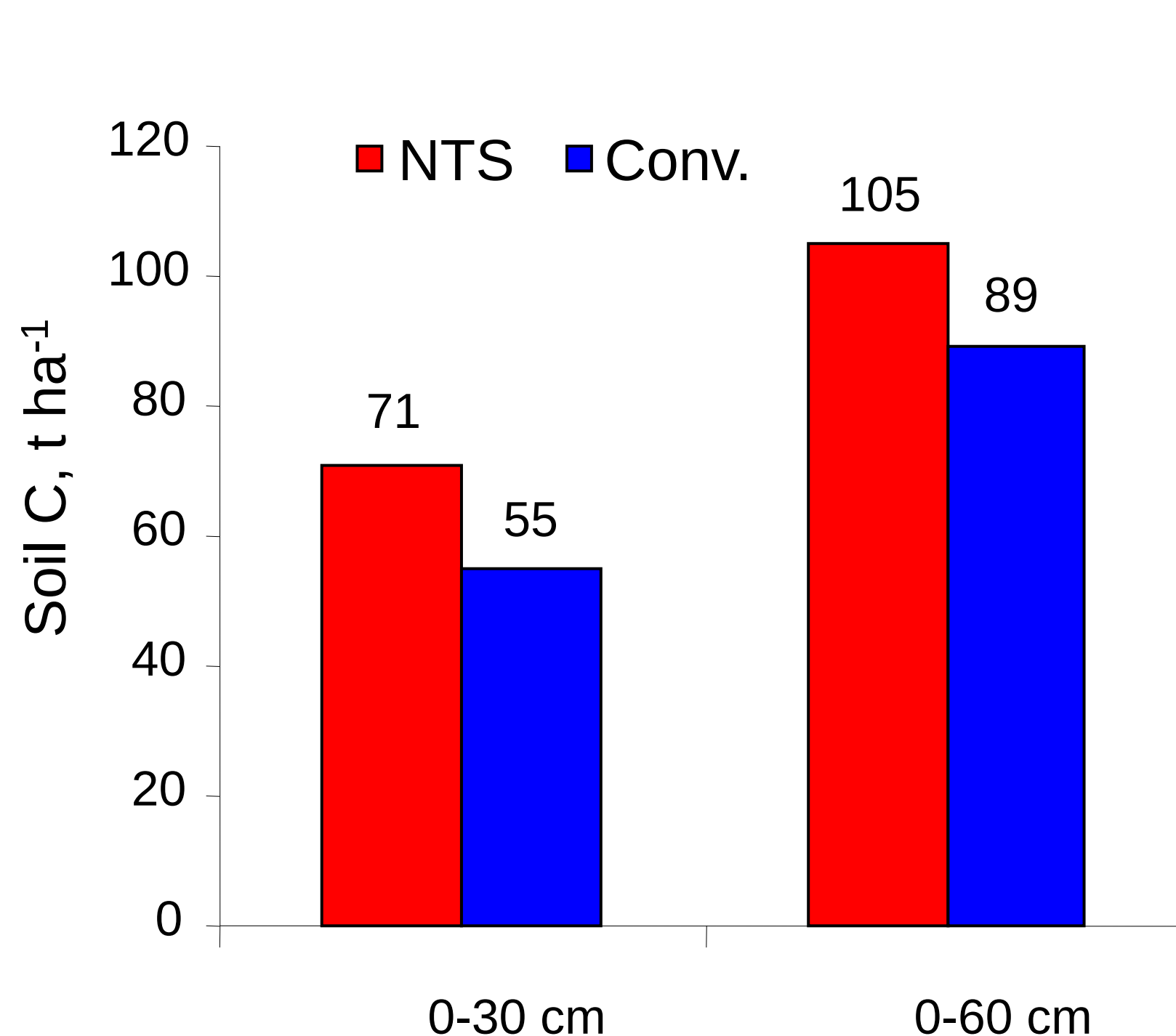


CO₂



Photos: M. A. Nogueira

No-tillage: soil conservation and C sink



Carbon stocks in different soil layers and management systems after 20 years.

Embrapa Soybean, Londrina/PR, 2008.

Difference: 16 t ha⁻¹
Rate: 800 kg ha⁻¹ yr⁻¹

2.93 t ha⁻¹ yr⁻¹
of eq-CO₂

In 20 years

58 t eq-CO₂ ha⁻¹

20.000 L diesel

Source: BABUJIA, L. C.; HUNGRIA, M.; FRANCHINI, J. C.; BROOKES, P. C. *Soil Biology & Biochemistry*, v. 42, p. 2174- 2181, 2010.

Crop-livestock-forest integration (CLFi)



Foto: Gabriel Rezende Faria

>15 Mha 2020 (80% CLI)
Recovery of degraded pastures

Crop-livestock-forest integration (CLFi)



Source: Embrapa

Soil cover

Protection against erosion



Source: Embrapa

Fodder for cattle

More offer of forage in critical dry periods.



Source: Nunes, 2019

Improvement of the system

Improving soil physical, chemical and biological properties

Inoculation of maize with *Azospirillum*

- ✓ Inoculation with *Azospirillum brasilense* increase yield by 20%;
- ✓ Stimulation of root system;
- ✓ Improve efficiency of use of N-fertilizer;
- ✓ Increase the effectiveness of the production system.



Inoculation of maize with *Azospirillum*

Stimulation of roots

- > Soil mining
- > Effectiveness of use of fertilizers
- > Access to water



Foto: Embrapa Soja



Foto: Embrapa Soja

Azospirillum in pasturelands

Faster soil coverage

> Biomass and soil cover

+ Uptake of nutrients

+ Roots



+Azo

-Azo

Foto: Leite 2019

+ *Azospirillum*

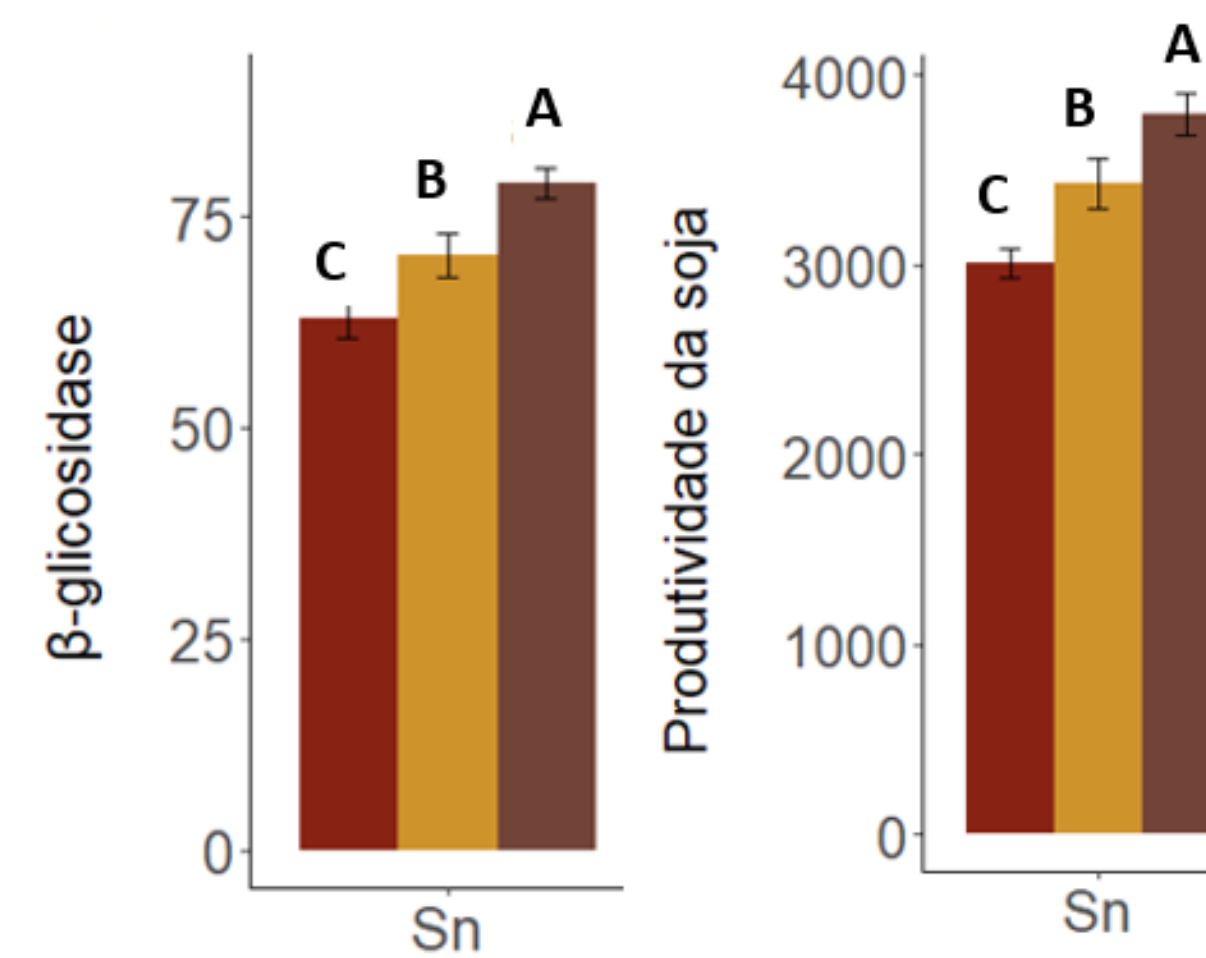


- *Azospirillum*



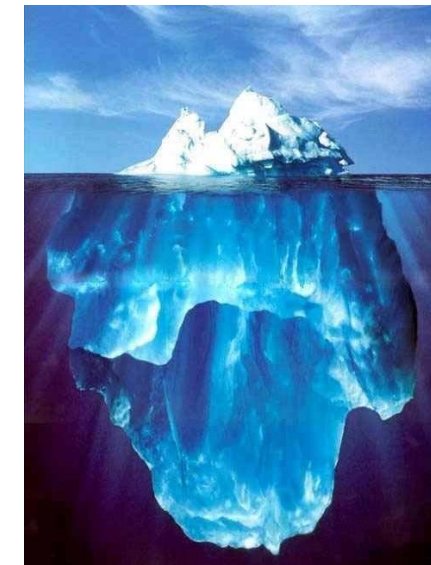
Foto: Embrapa Soja

Creating a biologically favorable environment



A. C. Charnobay, 2023

T1. Soybean NT/fallow



T3. Soybean NT/Ruzigrass



I.C. Mendes, Embrapa Cerrados e Fundação MT

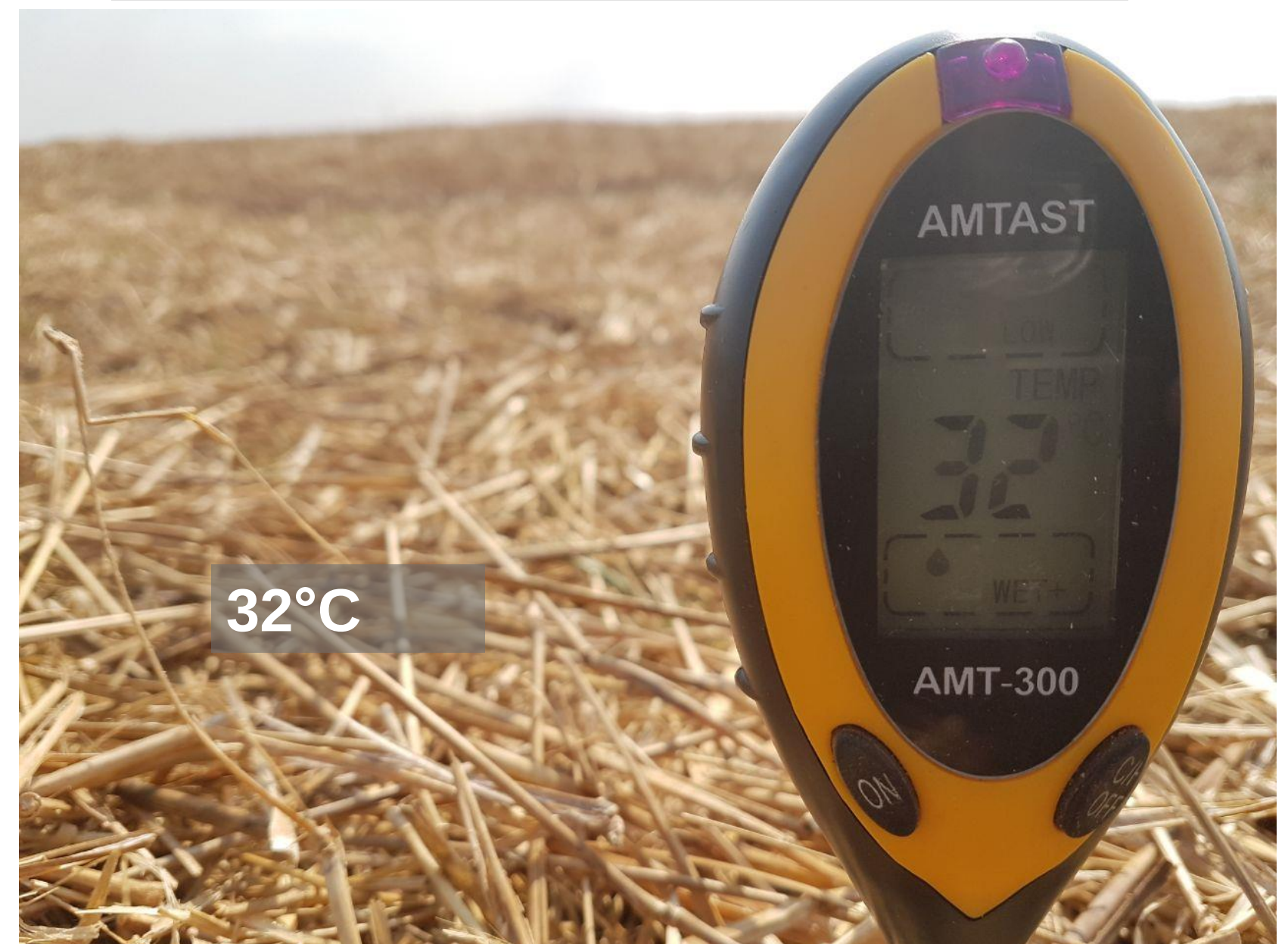
Creating a biologically favorable environment

Without ruzigrass



I.C. Mendes, Embrapa Cerrados e Fundação MT

With ruzigrass



Sousa et al. (1997)



Thank you



Brazilian Agricultural Research
Corporation
National Center for Soybean Research
Laboratory For Soil Biotechnology
Londrina Parana Brazil

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 Marco Nogueira



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COMEMORATIVA

50 ANOS DA
EMBRAPA SOJA

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SOJA**
CAMPINAS, SP

21 a 24 de julho de 2025

cbsoja.com.br



Embrapa

Diseases Research ***Embrapa Soybean***

Rafael Moreira Soares
Plant Pathologist



MINISTÉRIO DA
AGRICULTURA E
PECUÁRIA



Diseases – Soybean cycle

DAMPING OFF

- Anthracnose
- Phytophthora
- Rhizoctonia
- Sclerotium
- Fusarium
- Pythium

EARLY

- Brown Spot (*Septoria*)
- Cercospora Blight
- Bacterial Blight
- Rust
- Phytophthora

MIDDLE

- Powdery Mildew
- Rust
- Phytophthora
- Anthracnose
- Rhizoctonia
- Target Spot
- Sudden Death
- Sclerotinia Stem Rot
- Viruses
- Bact. Pustule

END OF CYCLE

- Brown Spot
- Cercospora Blight
- Charcoal Rot
- Rust



Research at *Embrapa Soybean*

Diseases identification

Isolations, storage, basic studies, etc.

Screening of germplasm – Breeding Program

Rust, stem canker, Phytophthora, frog-eye leaf spot, bacterial pustule, target spot, cyst and gall nematodes, mosaic and stem necrosis virus.

Diseases occurrence and cost

Diseases epidemiology and race variability

Diseases spray (fungicide and alternatives) and cultural management

Plant Pathology researchers

Maurício C. Meyer

Micology, diseases integrated management, biological and chemical control.

Claudine D. S. Seixas

Micology, virology, biological control, diseases integrated management, and phytopathogens collection.

Rafael M. Soares

Micology, bacteriology, diseases integrated management, chemical control, spray technology, genetic resistance.

Claudia V. Godoy

Micology, epidemiology, diseases integrated management, chemical and biological control.

Plant Pathology researchers



Regina M.V.B.C. Leite

Sunflower diseases management, and genetic resistance



José Mauro C. Castro

Nematology
Biology, epidemiology, and genetic resistance to soybean nematodes

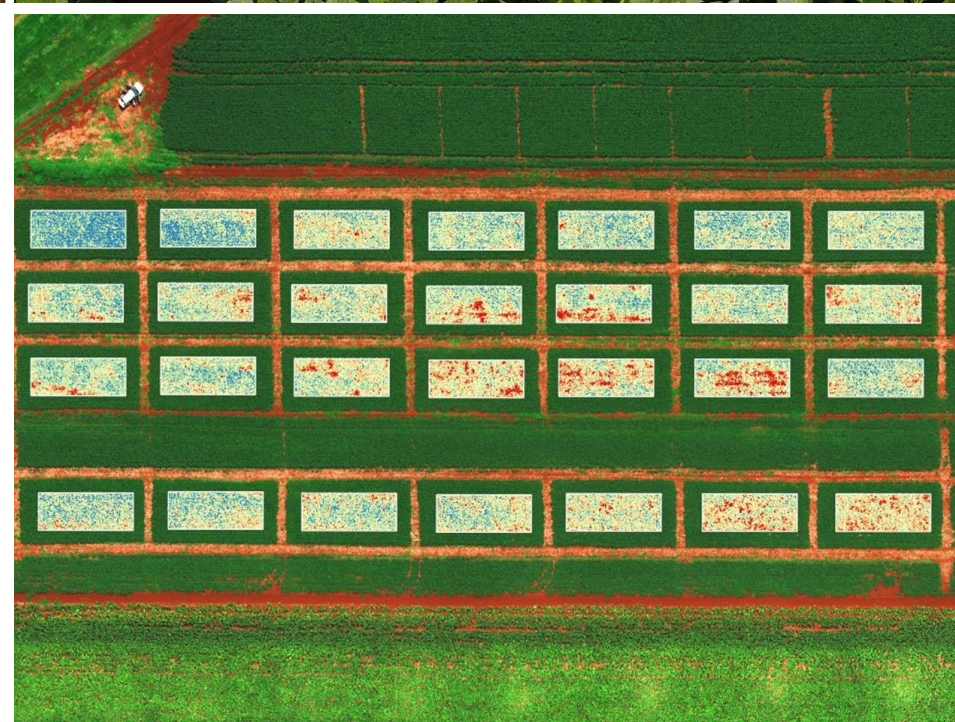


Leandro E.C. Diniz

Microorganisms genetic diversity, plant gene editing and transformation.

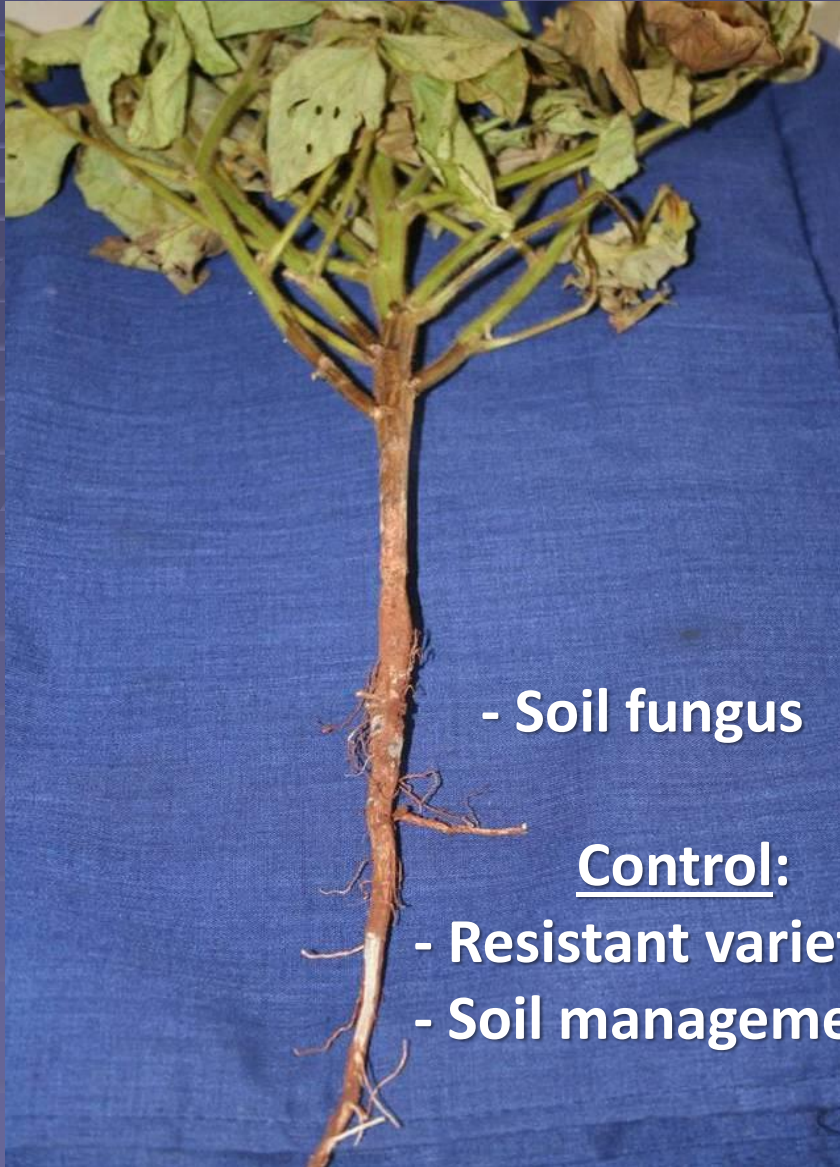






PHYTOPHTHORA ROOT ROT

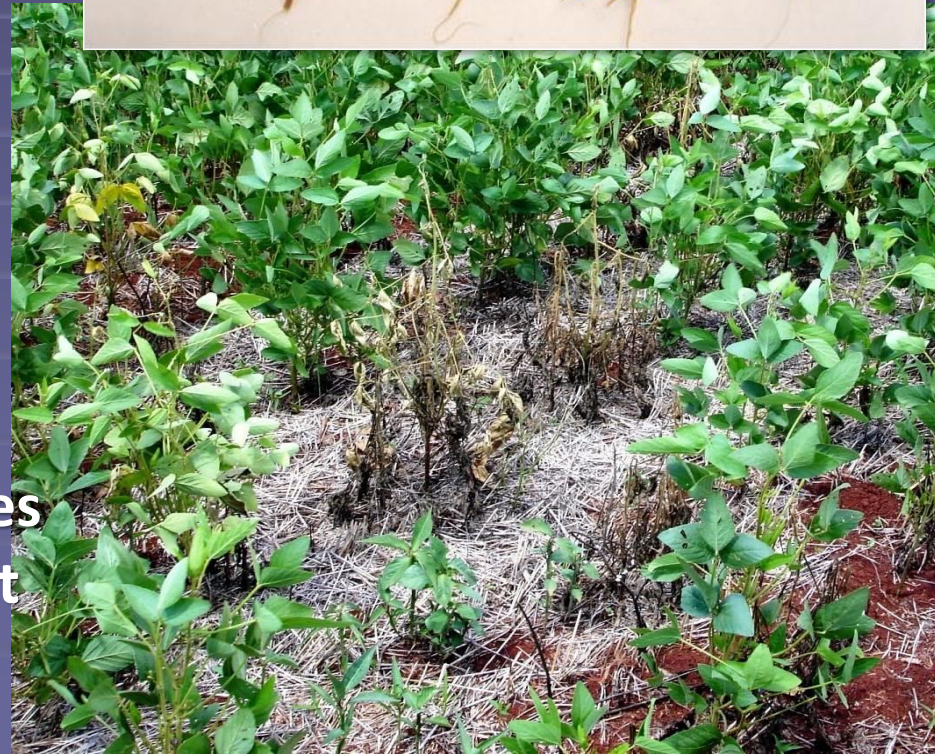
Phytophthora sojae



- Soil fungus

Control:

- Resistant varieties
- Soil management



CHARCOAL ROT

Macrophomina phaseolina

- Soil fungus
- Control:
 - Resistant varieties???
 - Soil management



Sand soil + compactation + dry period= disease



Foto: Ademir Henning

CERCOSPORA BLIGHT & LEAF SPOT

Cercospora kikuchii

- Losses 8-15%
 - Control:
 - Resistant varieties
 - Clean seeds
 - Crop rotation
 - Adequate fertilization
 - Seed Treatment
 - Foliar Fungicides
- R3 to R5.1
(benzimidazoles, triazoles,
strobilurins)



TARGET SPOT

Corynespora cassiicola

-Losses: 18 to 32%

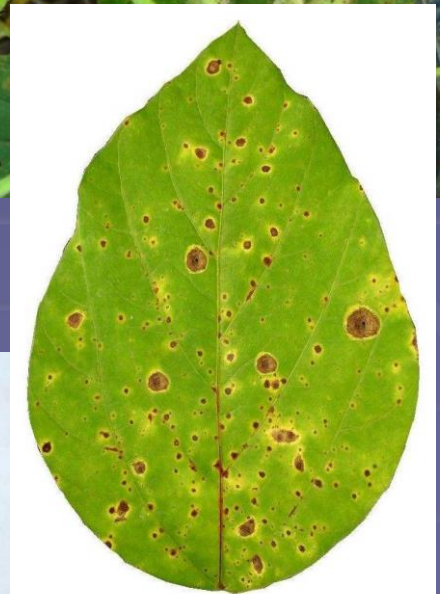
-Control:

-Crop rotation

-Resistant varieties ??

-Fungicides

(benzimidazol – carbendazin,
thiophanate methyl ??; triazoles;
carboxamides)



CYST NEMATODE

Heterodera glycines

- Small plants
- Controle:
 - Prevention: clean machinery.
 - Crop rotation
 - Clean seeds
 - Soil
 - Resistant varieties*



CYST NEMATODE



GALL NEMATODE

Meloidogyne incognita e *M. javanica*

- Small plants.
- Control:
- Crop rotation
- Soil prepare
- Resistant varieties



SOYBEAN RUST

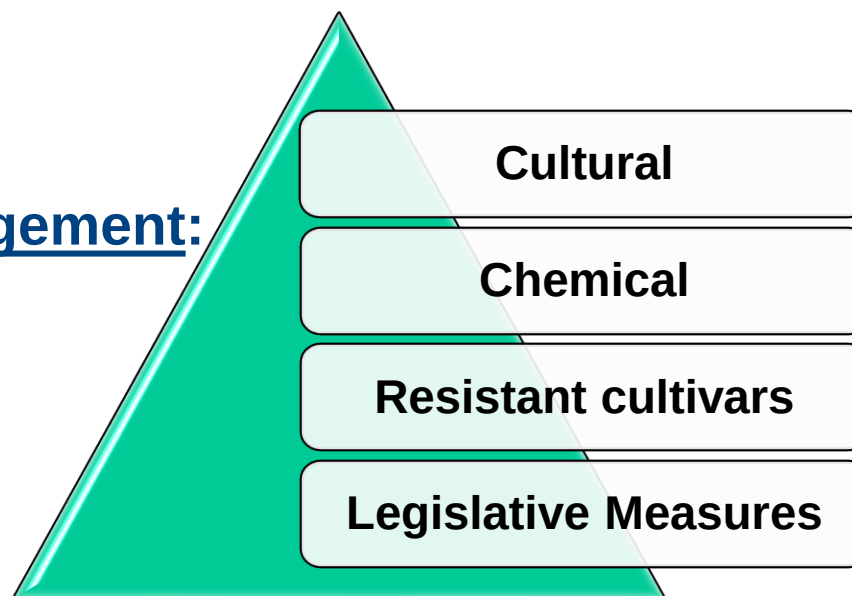
Phakopsora pachyrhizi





SOYBEAN RUST

Integrated management:



Resistant cultivars



TMG 7060 IPRO

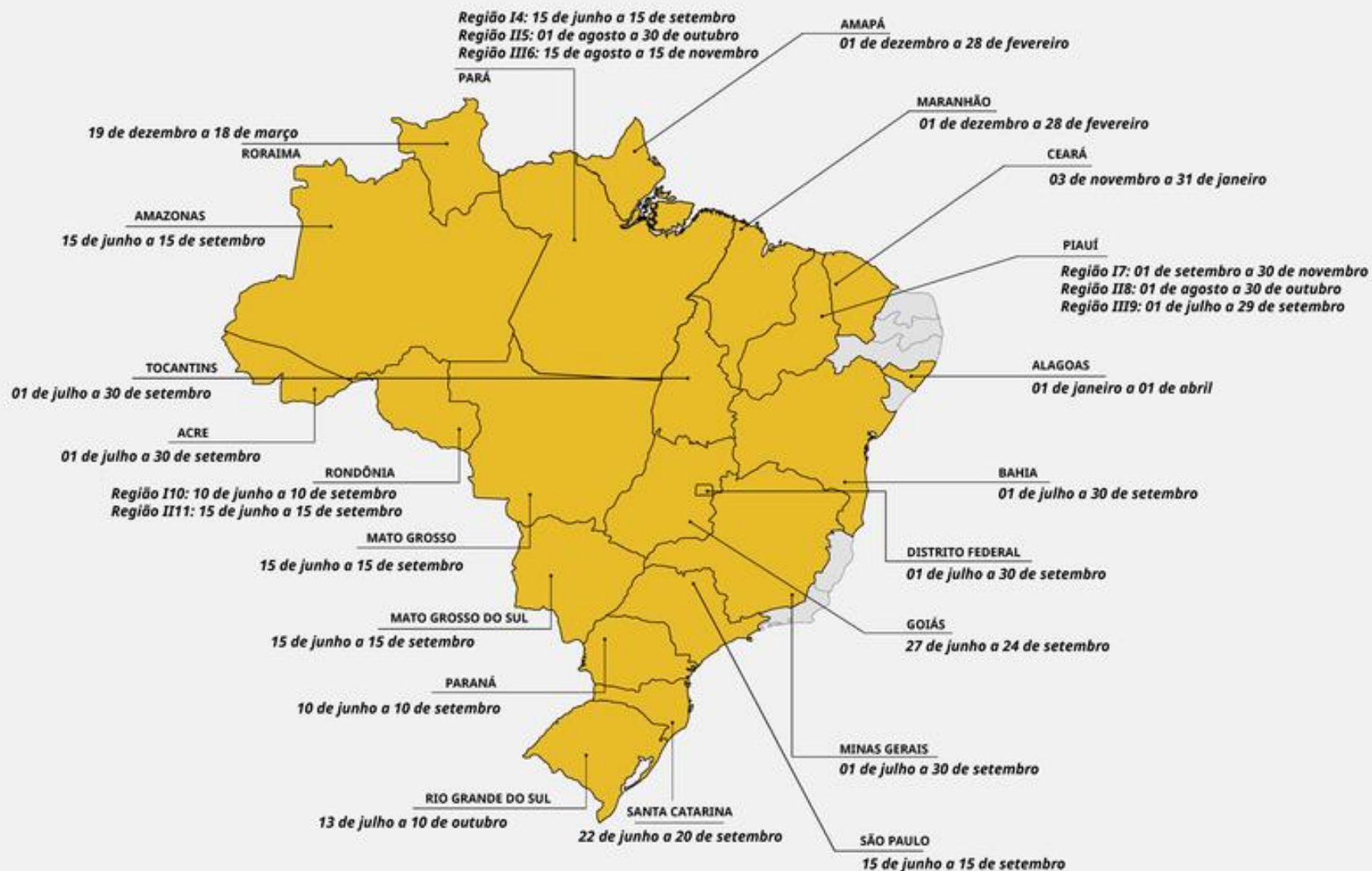


BRS 511



Susceptible

Sanitary Empty (free host period)



Spontaneous soybean

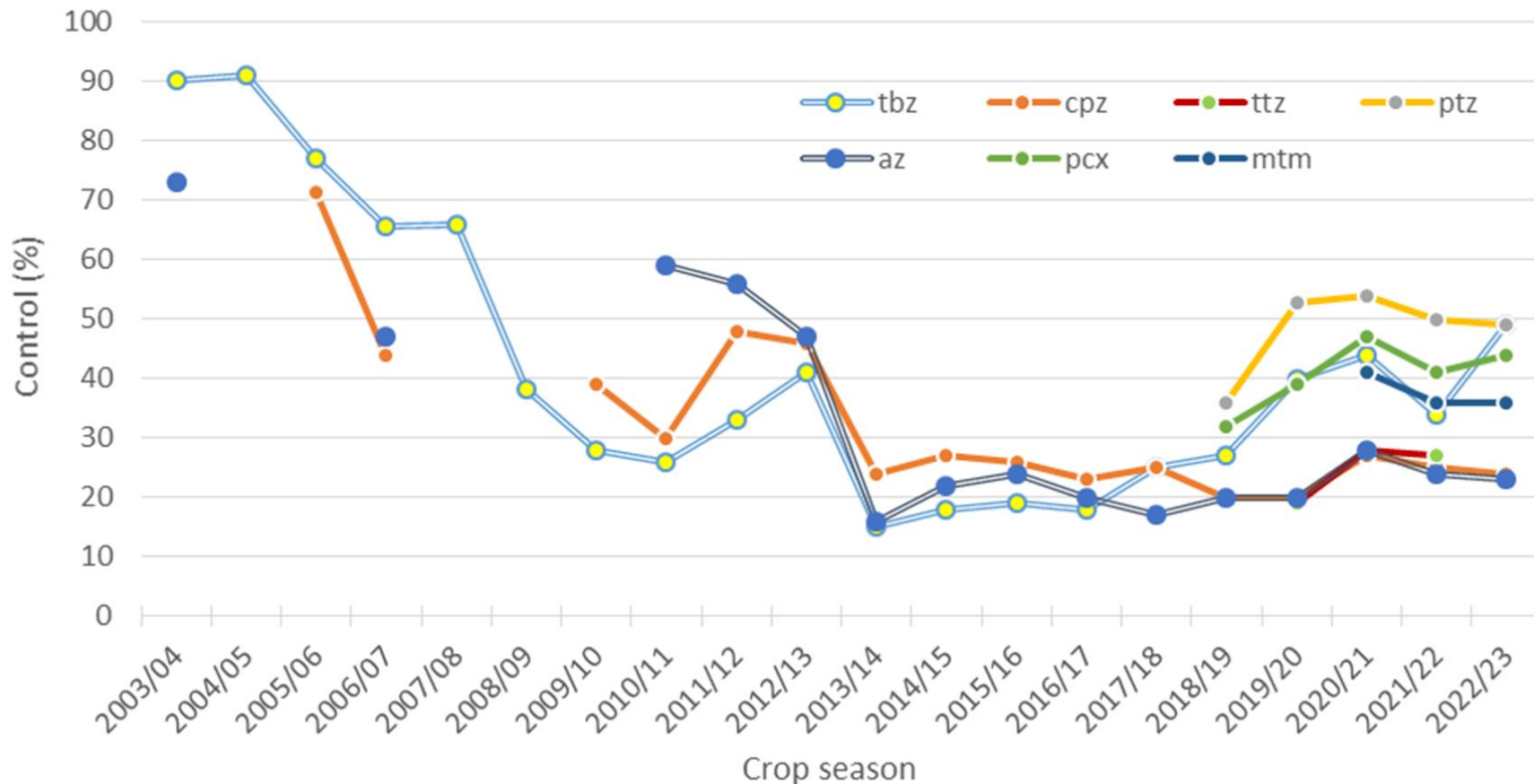


Fungicide spray



Eficiency reduction of fungicides

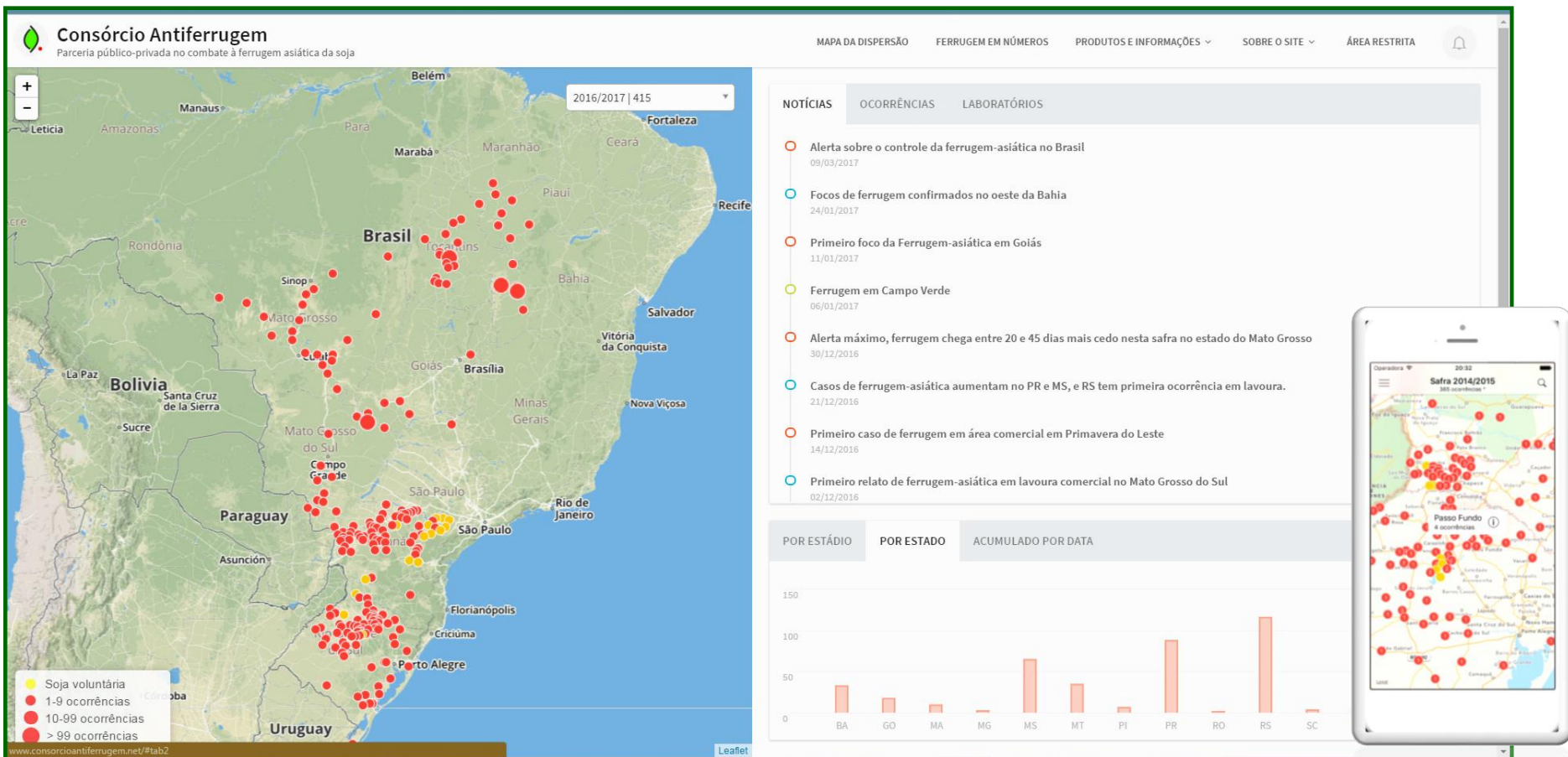
Performance of DMI and QoI fungicides on the control of ASR



TBZ (tebuconazol), CPZ (ciproconazol), TTZ (tetraconazol) e PTZ (protioconazol) - (IDM)
AZ (azoxistrobina), PCX (picoxistrobina) E MTM (metominostrobin) - (IQe)

MONITORING SITE

www.consorcioantiferrugem.net



MONITORING

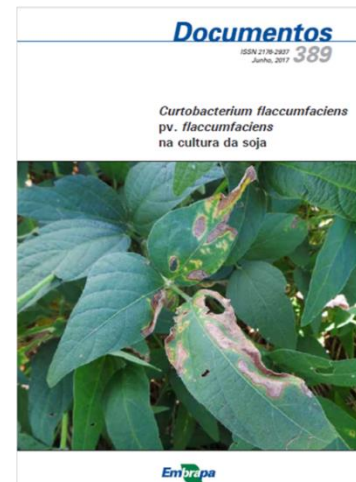
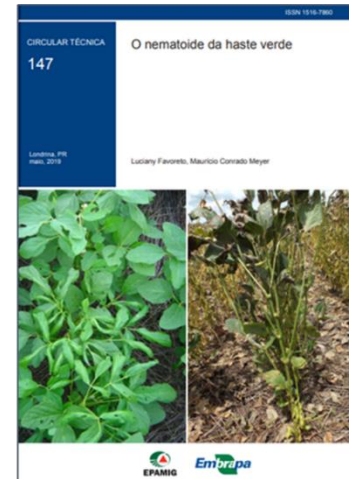


TECHNOLOGY TRANSFER

COURSES, TRAININGS, FIELD DAYS,
INTERVIEWS, PUBLICATIONS



Publications





Thank you!

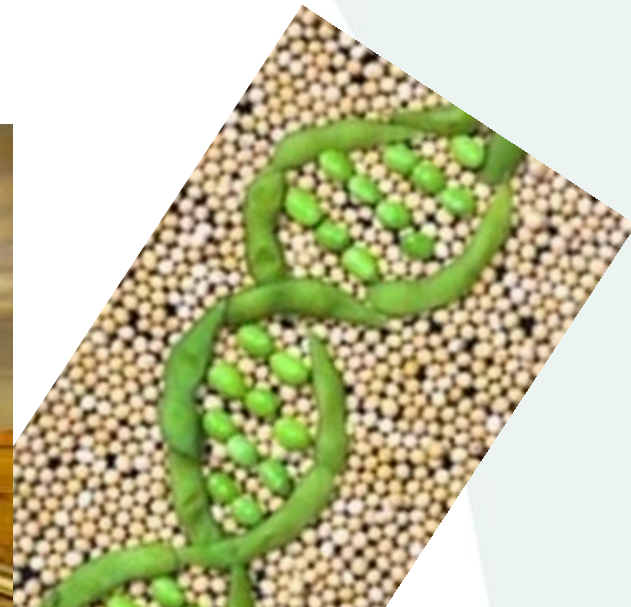
rafael.soares@embrapa.br
www.embrapa.br/soja

Embrapa 50 ANOS

MINISTÉRIO DA
AGRICULTURA E
PECUÁRIA

GOVERNO FEDERAL
BRASIL
UNIÃO E RECONSTRUÇÃO

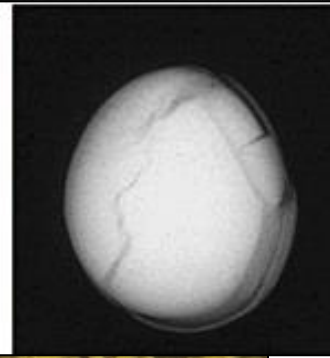
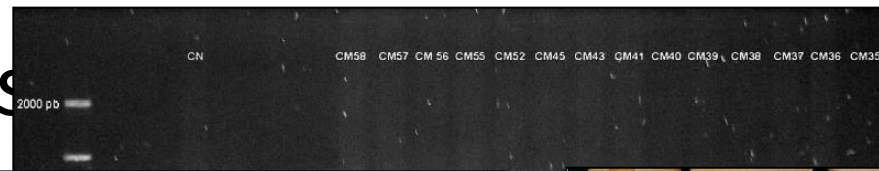
Soybean seed quality and technology



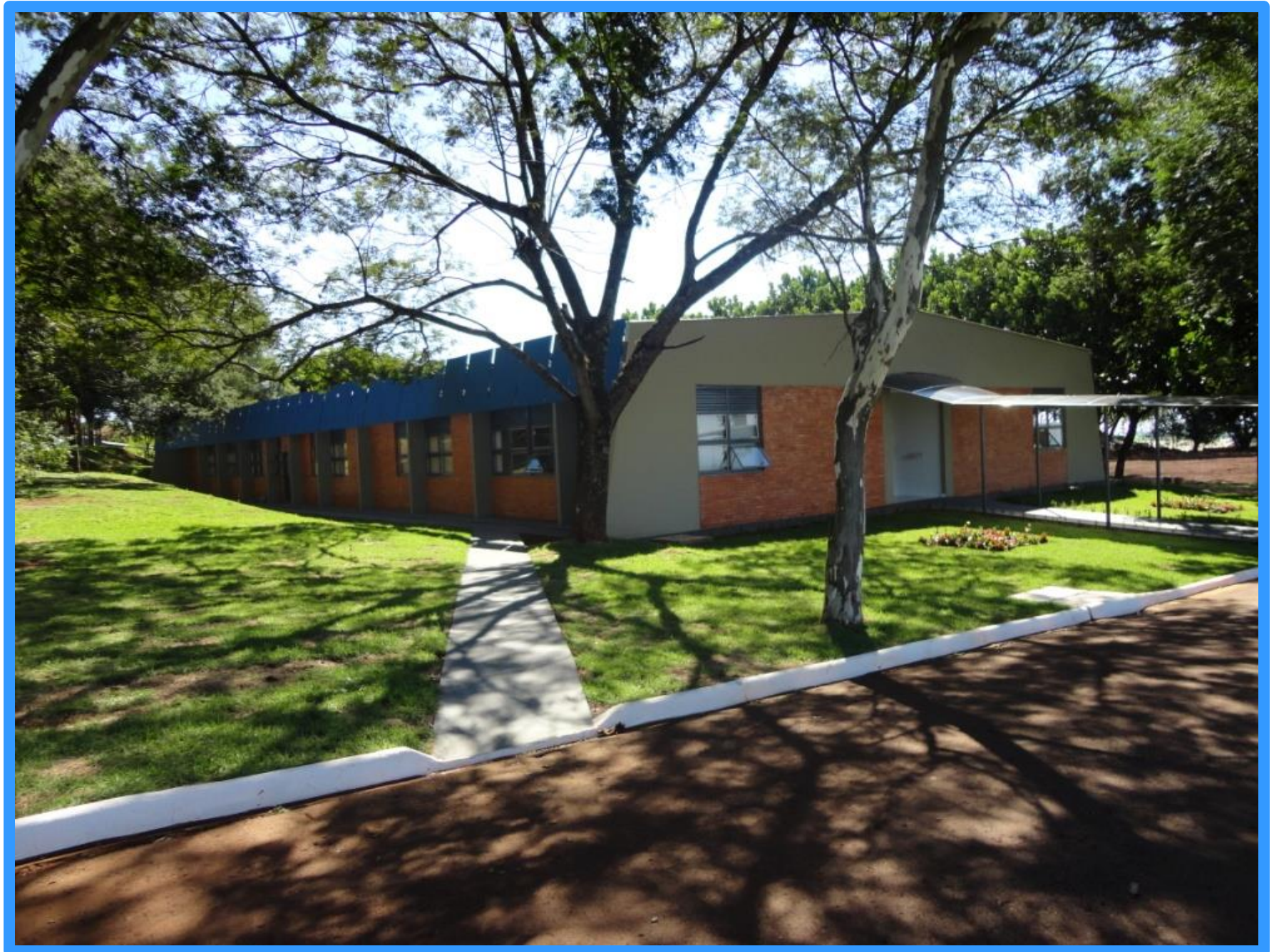
Fernando Augusto Henning
Jose de Barros França-Neto
Francisco Krzyzanowski

Seed Quality

✓ Genetic



Seed Science and Technology Center



Post harvest



Chemical and Molecular Analyses



Seed Pathology



Seed Physiology and Technology



Vigor training - 16 editions, 573 participants



17º Curso de Vigor em Sementes de Soja

Embrapa Soja, Londrina, PR, 8 a 12 de julho de 2024



Training in TZ and Seed Pathology – 38 editions > 4000 participants



The harvest depends on what you sow (plant)!

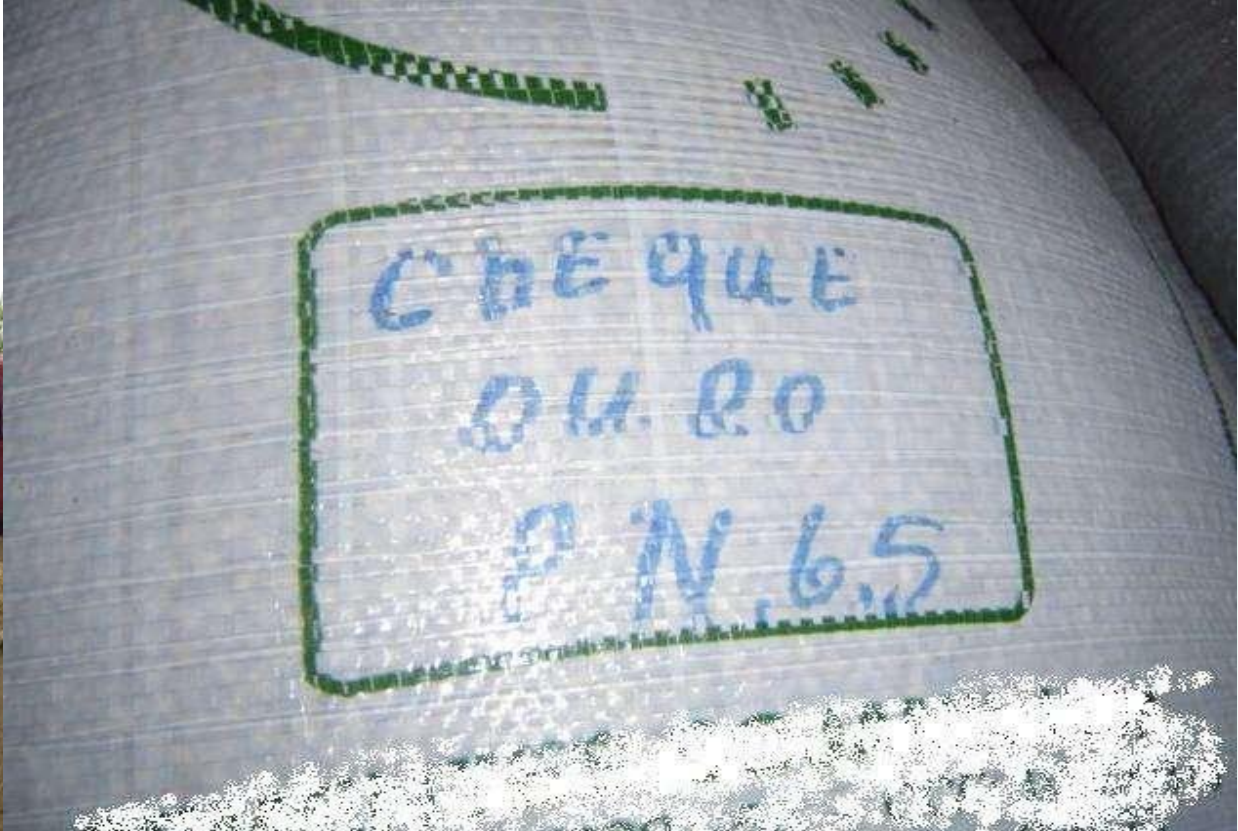
SeedWORLD

*World
Seed Day*
COMMEMORATION

**«There are no good crops
without good seeds»**

Use certified (official) seeds: C1 & C2 or S1 & S2

(guarantee of genetic purity, physiological quality and disease-free!)



Feijão - 90%



Arroz - 44%



Algodão - 43%



Soja - 29%



Trigo - 25%

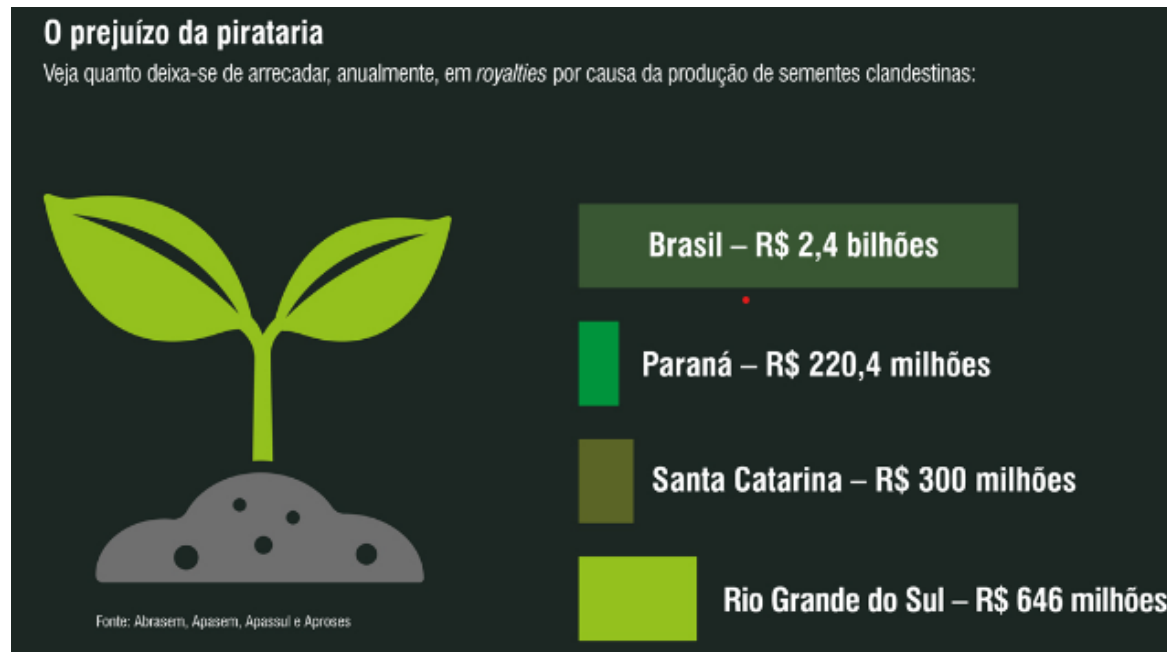


Milho - 8%



The risks to agriculture.....

- Destructuring of research
- Dismantling of the seed park
- Vulnerability to new pests and diseases
(stem canker, frog's eye, White Mold! etc.)
- Tax evasion
- Misinformation in the field
- Productivity reduction
- Loss of external competitiveness



The farmer`s risks!

Phytosanitary - Spread of pests and diseases

Ex: nematodes, weeds, diseases (CH, CS, PB, MB)

Loss of genetic performance - purity

Mixtures, low performance, non-uniformity

Regional adaptation (Smuggled soy!)

Drop in productivity

Physiological quality – (Germination & vigor)

Detachment from technology and training

And...

Low performance, Low productivity and Low profitability!

Seed production

- ✓ 3,5 millions of tons per year
- ✓ > 600 millions of dollars
- ✓ 420 producers
- ✓ > 300 000 people
- ✓ > 15 breeding programs



Soybean Seed treatment in Brazil

1^a Recommendation -

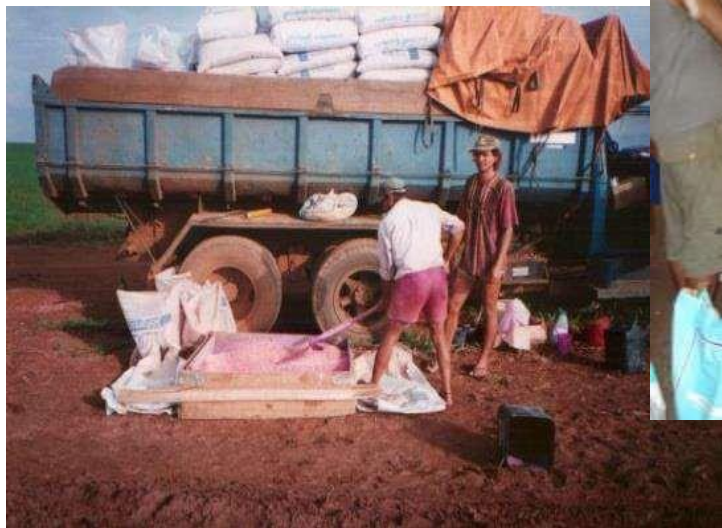
- **1981- Center – South**
- **1983- Extended to Brazil (RS & SC)**

- Fungicides (contact and systemic)
- Insecticides
- Nematicides
- Micronutrients (Co, Mo, Zn, Copper, Mn)
- Biostimulants
- Hormones & growth regulators
- Other (polymers, pigments)
- Inoculants...

The evolution...

**Products, equipments, people,
knowledge...**

On farm – 70`s



80`s – 90`s



**Industrial
Seed
Treatment**





Fungicide efficiency (benzimidazóis)



Thiabendazole 15 g i.a.
per 100kg seed

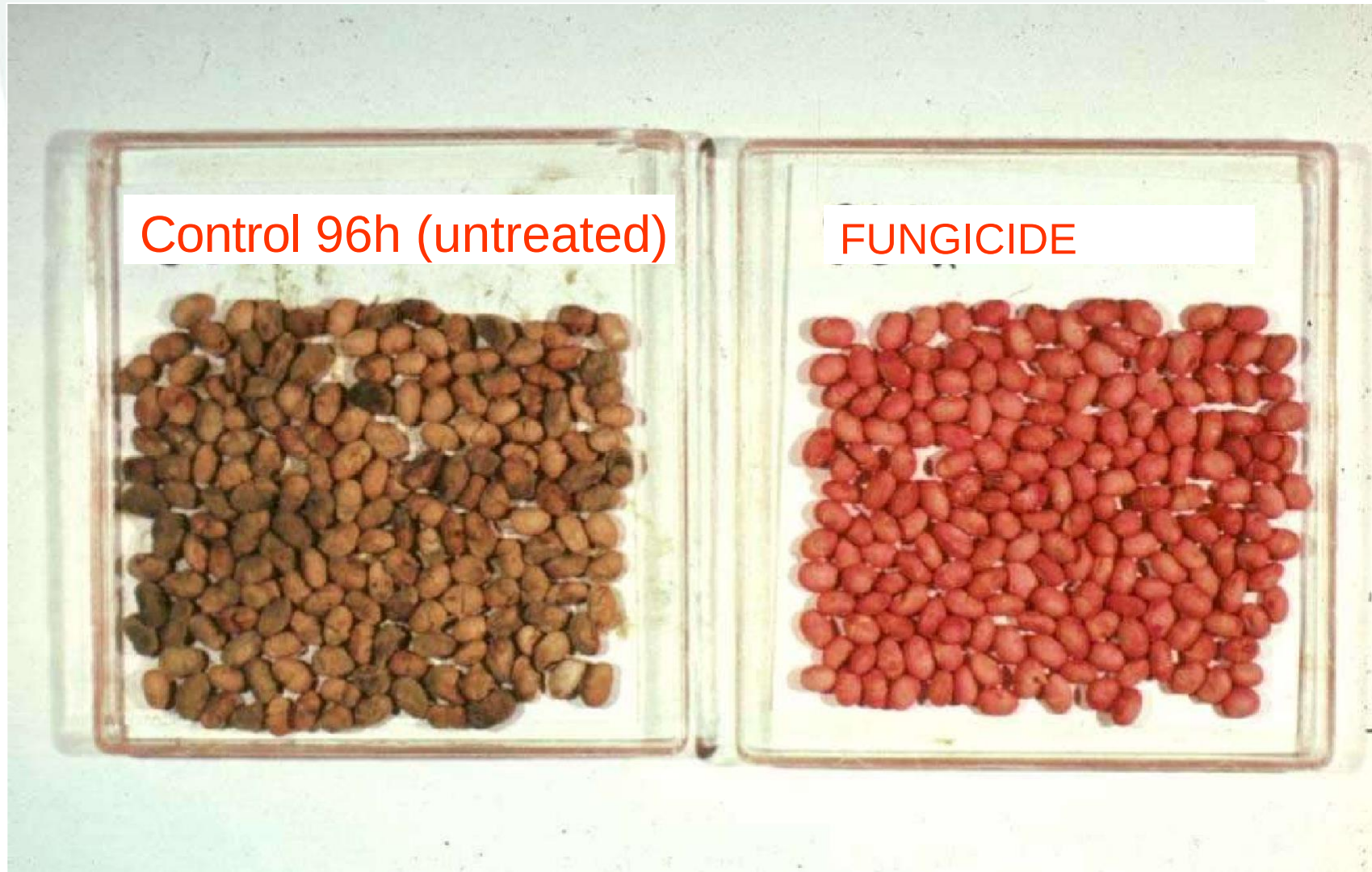


Control
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Drought conditions x seed emergence



Action of fungicide – under drought after sowing (*Aspergillus flavus*)

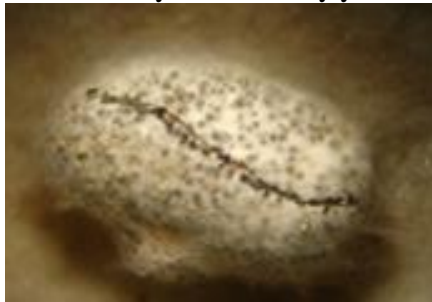


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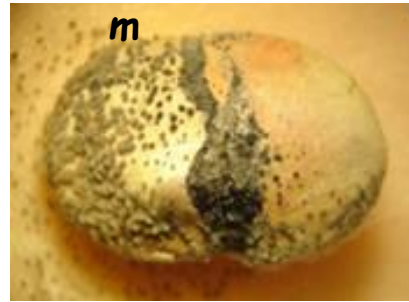
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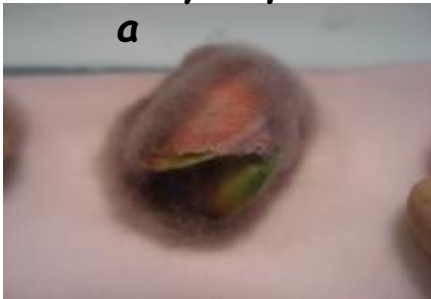
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Cercospora



*Corynespor
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Sclerotinia



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Tratamentos Ingrediente ativo	Dose (mL ou g l.a./100kg de sementes)	ID de <i>Rhizoctonia solani</i> (%)	Controle (%)
1. Testemunha inoculada	-	45,9 A	-
2. Testemunha não inoculada		0,0 D	-
3. carboxina+tiram ¹		0,9 B	55
4. ipconazol+tiram		2,4 C	73
5. ipconazol		9,0 C	80
6. tiofanato metílico+clorotalonil ¹		9,5 C	79
7. tiofanato metílico+fluazinam ¹		8,7 CD	81
8. tiofanato metílico+fluazinam		8,3 CD	82
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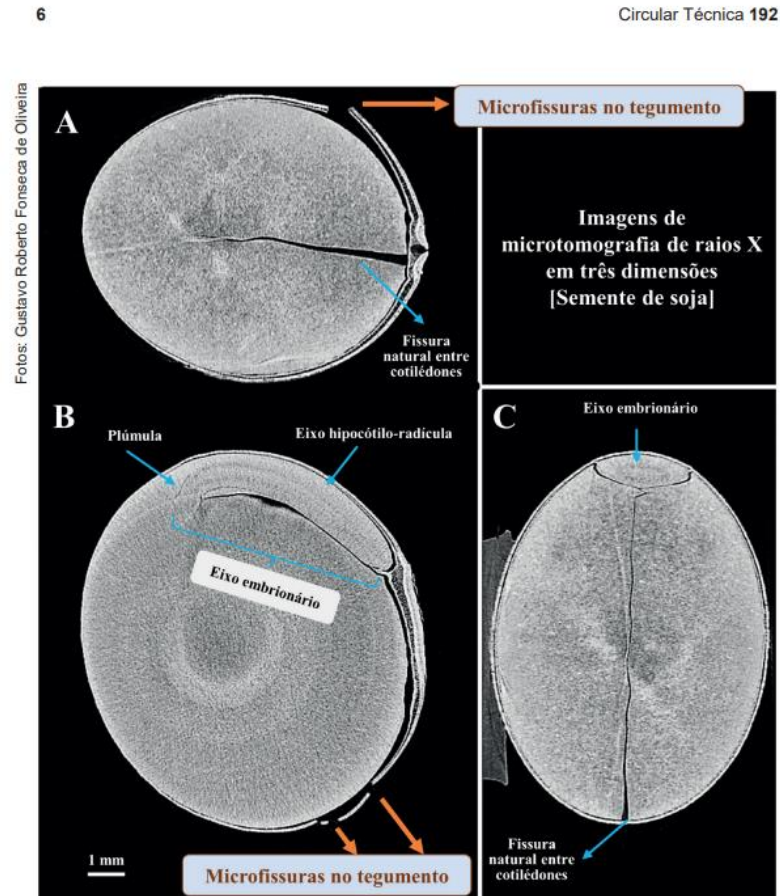
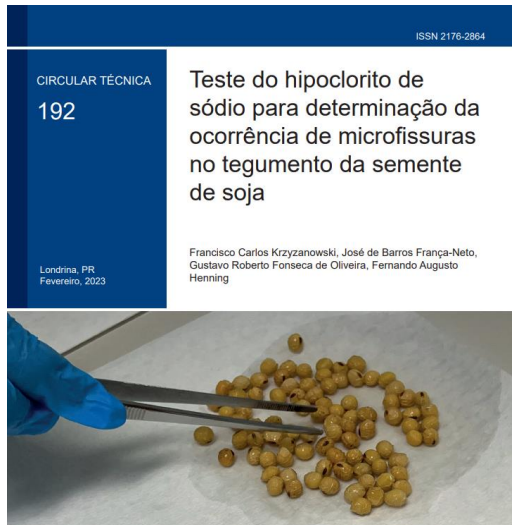
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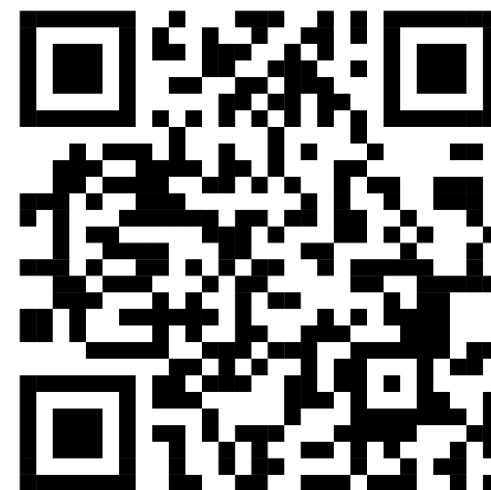
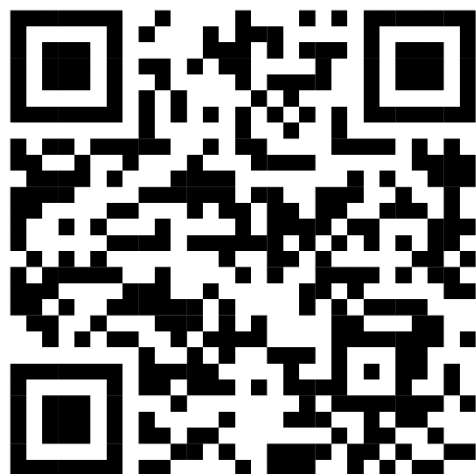
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GUIA PRÁCTICA PARA IDENTIFICAR LOS HONGOS MÁS FRECUENTES EN SEMILLAS DE SOJA

Ademir Assis Henning



2018: 3^a edition

2022: 4^a edition



Storage conditions

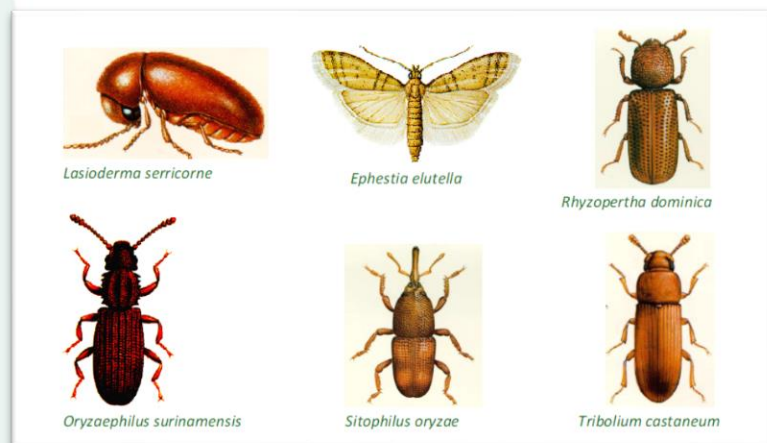


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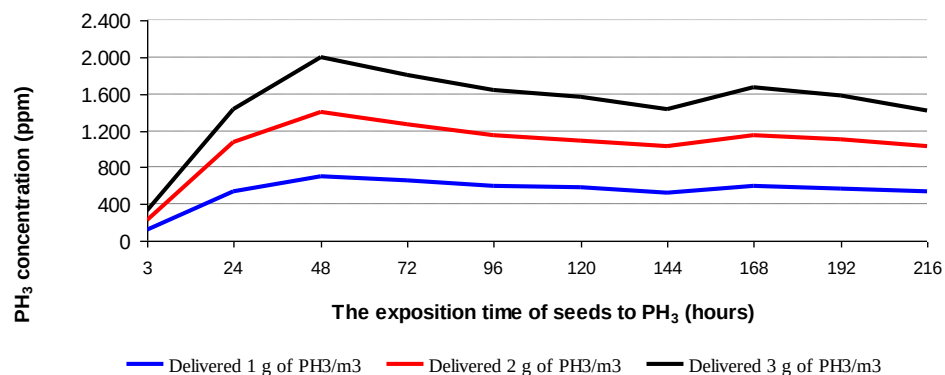
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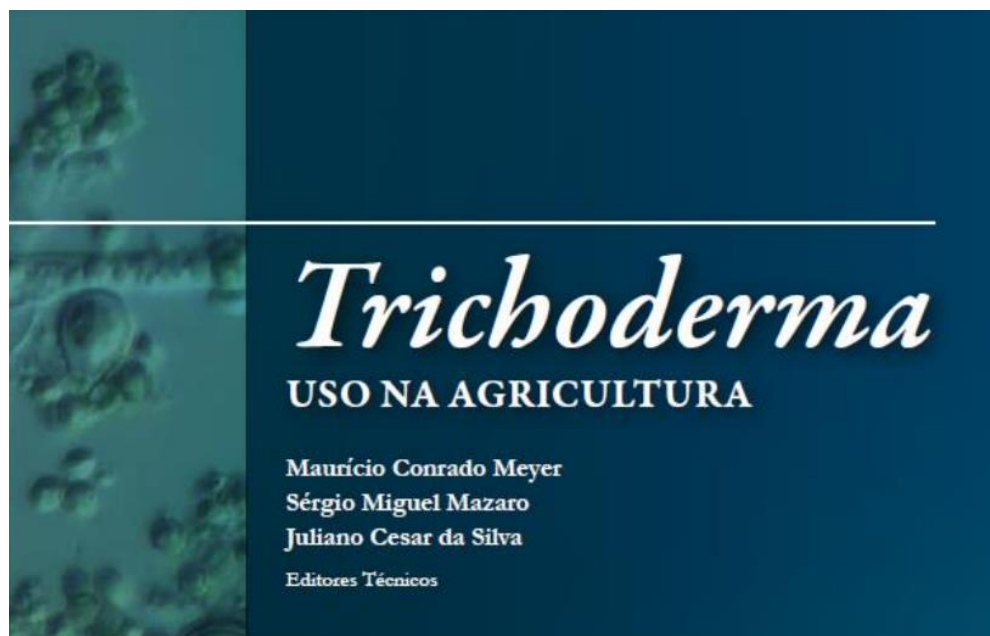
Meta-analysis | [Open Access](#) | [Published: 23 May 2022](#)

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Agronomy for Sustainable Development **42**, Article number: 45 (2022) | [Cite this article](#)

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-  embrapa.br/soja/radar

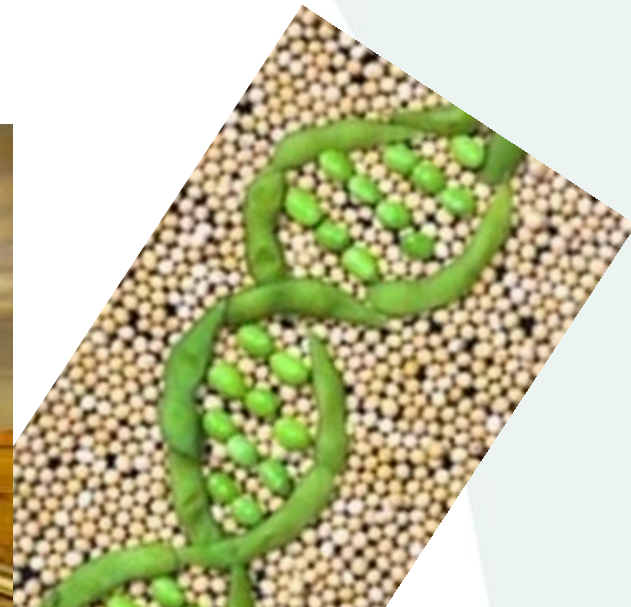
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Fernando Henning

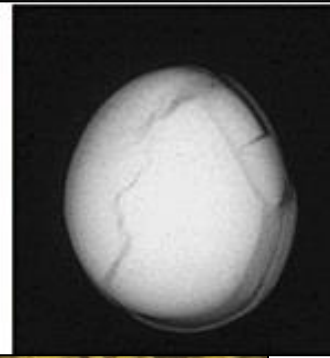
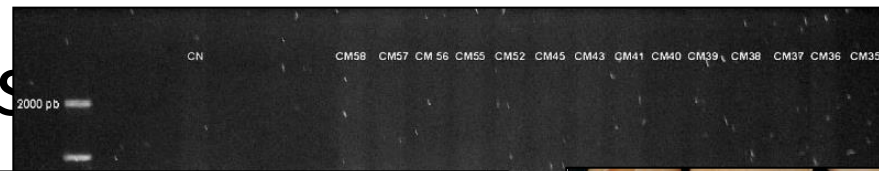
fernando.henning@embrapa.br



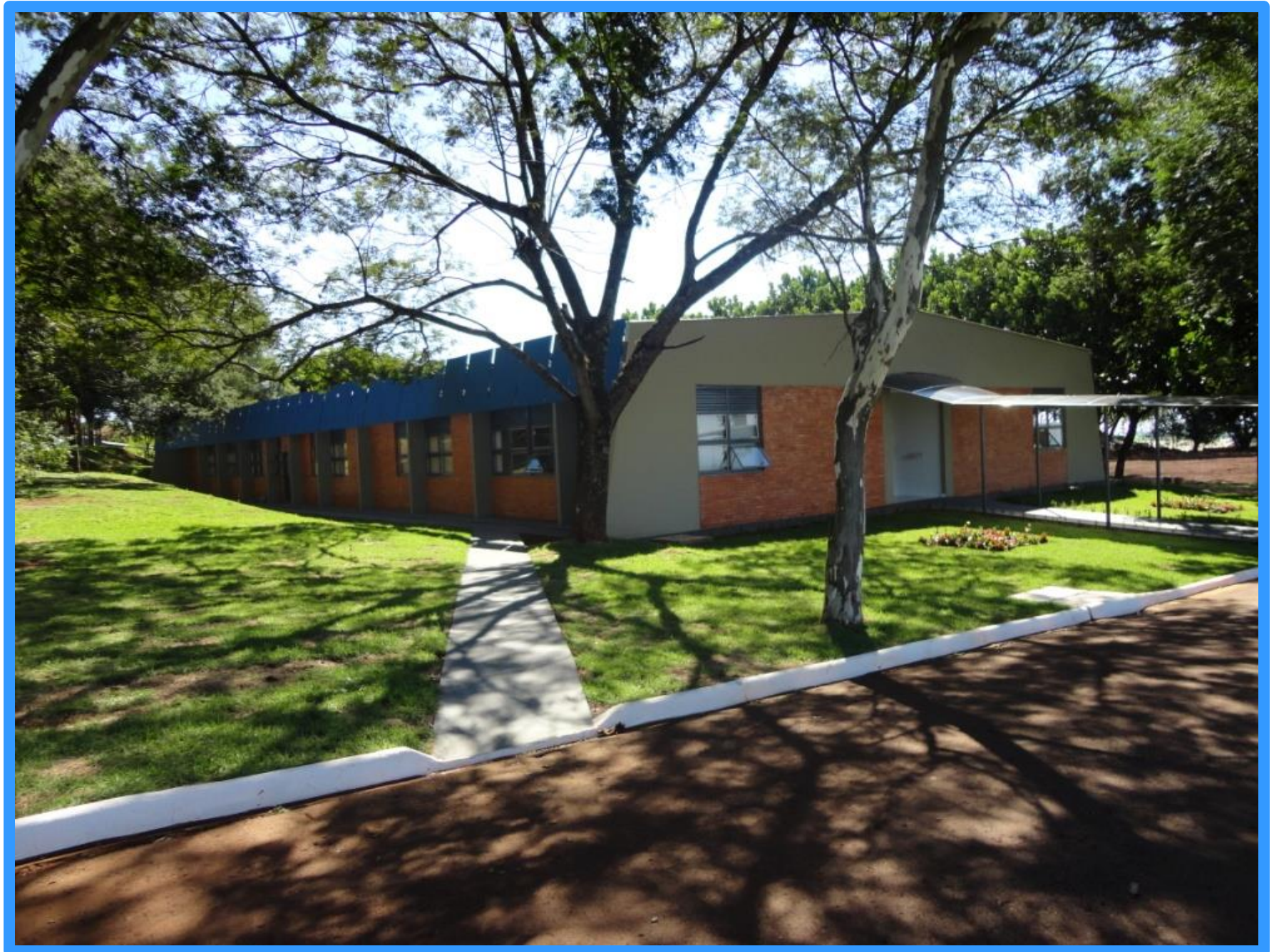
Soybean seed quality and technology



Fernando Augusto Henning
Jose de Barros França-Neto
Francisco Krzyzanowski



Seed Science and Technology Center



Post harvest



Chemical and Molecular Analyses



Seed Pathology



Seed Physiology and Technology



Vigor training - 16 editions, 573 participants



17º Curso de Vigor em Sementes de Soja

Embrapa Soja, Londrina, PR, 8 a 12 de julho de 2024



Training in TZ and Seed Pathology – 38 editions > 4000 participants



The harvest depends on what you sow (plant)!

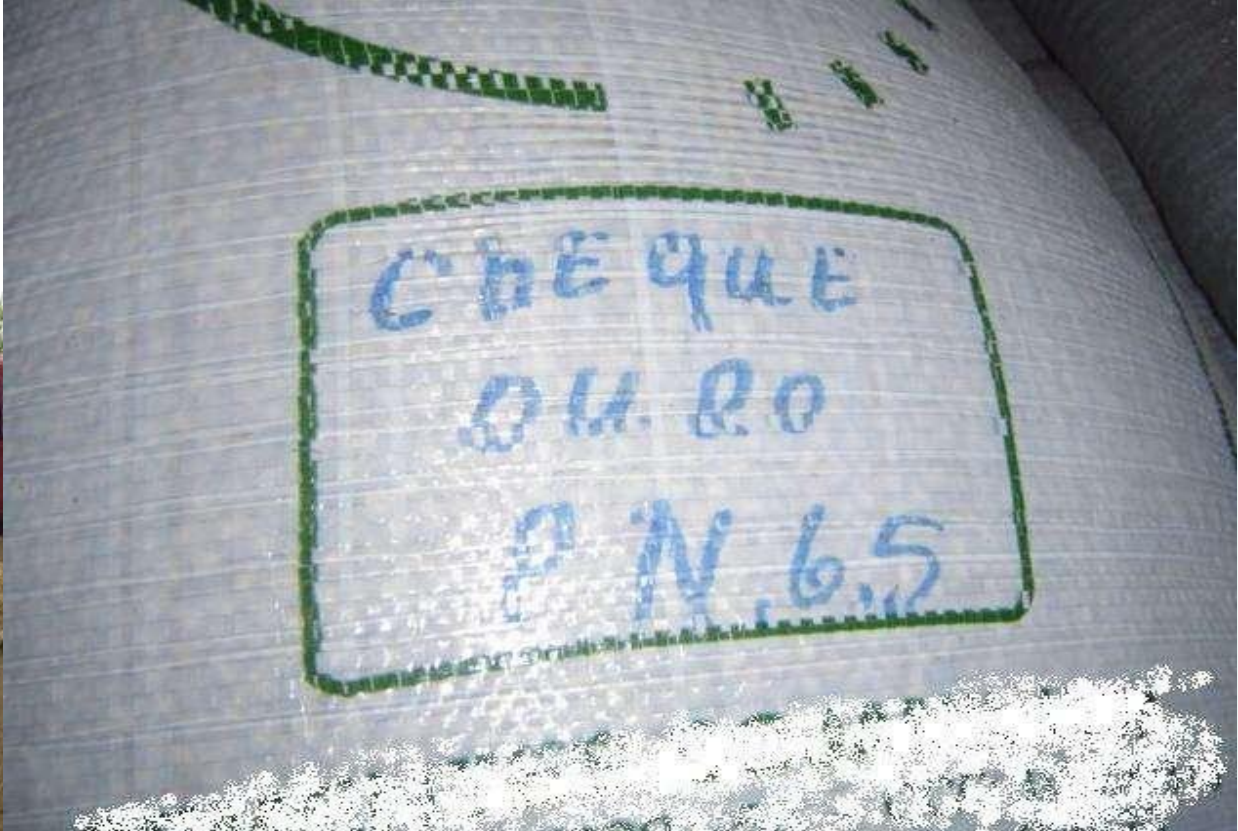
SeedWORLD

World
Seed Day
COMMEMORATION

**«There are no good crops
without good seeds»**

Use certified (official) seeds: C1 & C2 or S1 & S2

(guarantee of genetic purity, physiological quality and disease-free!)



Feijão - 90%



Arroz - 44%



Algodão - 43%



Soja - 29%



Trigo - 25%

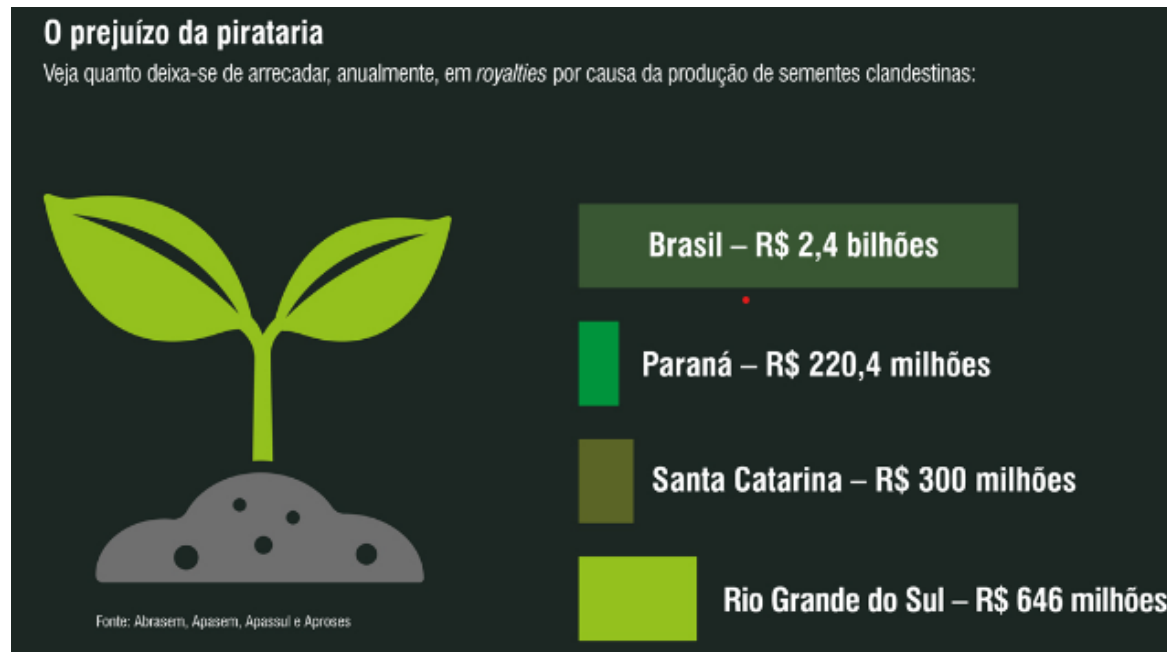


Milho - 8%



The risks to agriculture.....

- Destructuring of research
- Dismantling of the seed park
- Vulnerability to new pests and diseases
(stem canker, frog's eye, White Mold! etc.)
- Tax evasion
- Misinformation in the field
- Productivity reduction
- Loss of external competitiveness



The farmer`s risks!

Phytosanitary - Spread of pests and diseases

Ex: nematodes, weeds, diseases (CH, CS, PB, MB)

Loss of genetic performance - purity

Mixtures, low performance, non-uniformity

Regional adaptation (Smuggled soy!)

Drop in productivity

Physiological quality – (Germination & vigor)

Detachment from technology and training

And...

Low performance, Low productivity and Low profitability!

Seed production

- ✓ 3,5 millions of tons per year
- ✓ > 600 millions of dollars
- ✓ 420 producers
- ✓ > 300 000 people
- ✓ > 15 breeding programs



Soybean Seed treatment in Brazil

1^a Recomendation -

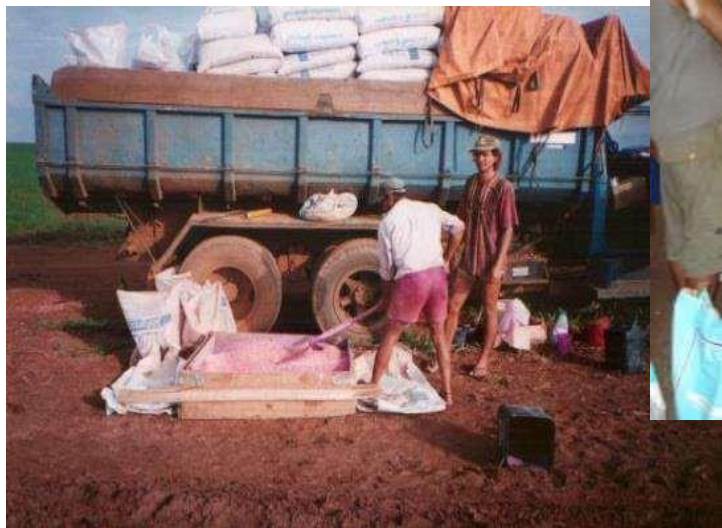
- **1981- Center – South**
- **1983- Extended to Brazil (RS & SC)**

- Fungicides (contact and systemic)
- Insecticides
- Nematicides
- Micronutrients (Co, Mo, Zn, Copper, Mn)
- Biostimulants
- Hormones & growth regulators
- Other (polymers, pigments)
- Inoculants...

The evolution...

**Products, equipments, people,
knowledge...**

On farm – 70`s



80`s – 90`s



Industrial
Seed
Treatment





Fungicide efficiency (benzimidazóis)



Thiabendazole 15 g i.a.
per 100kg seed

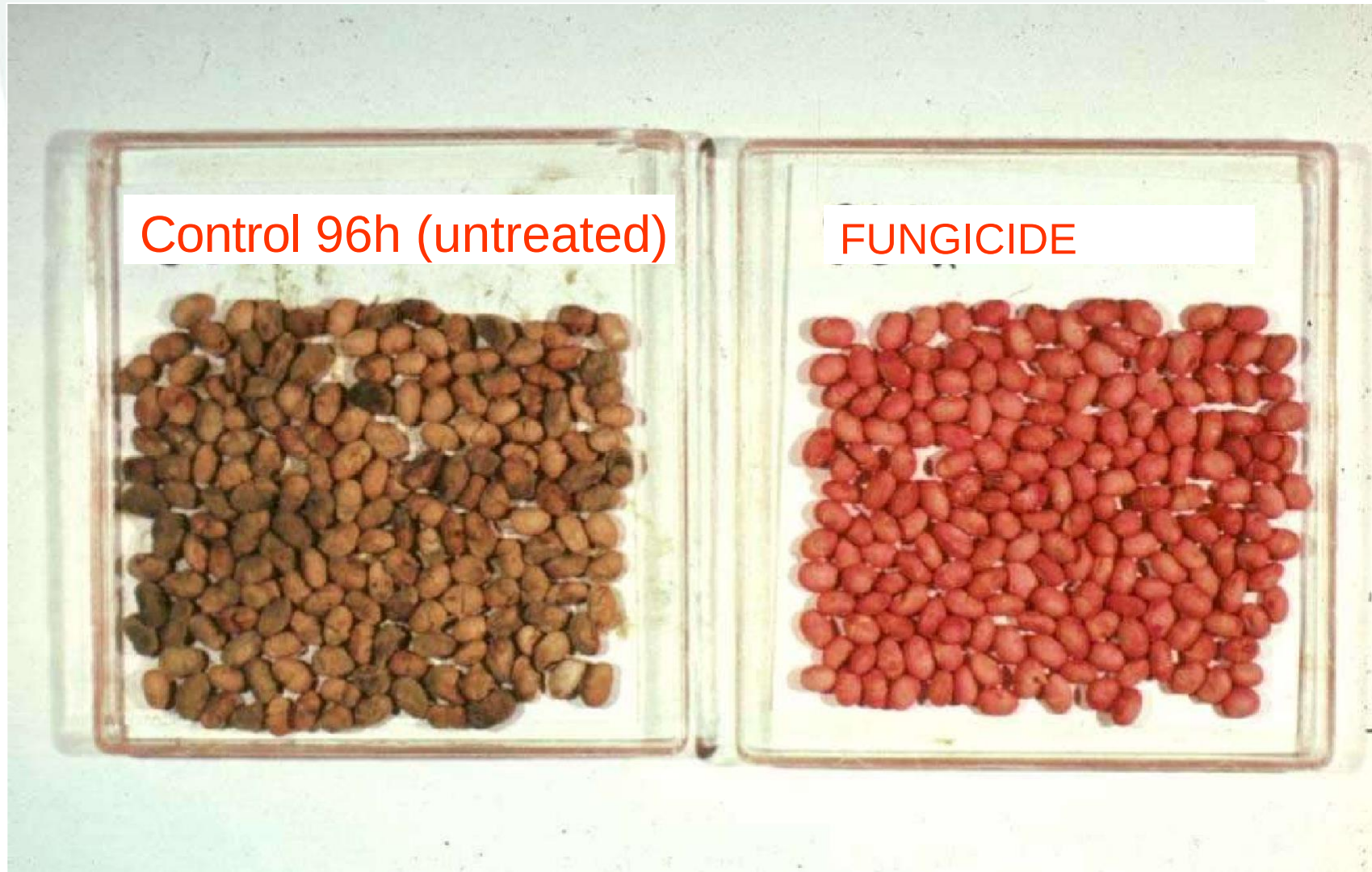


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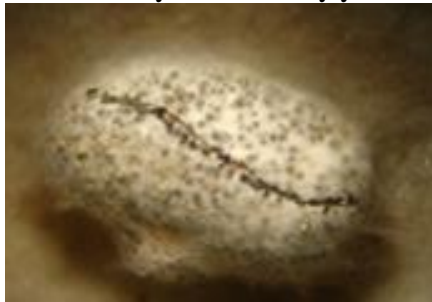


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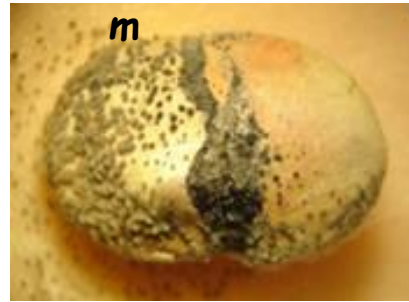
Fusarium



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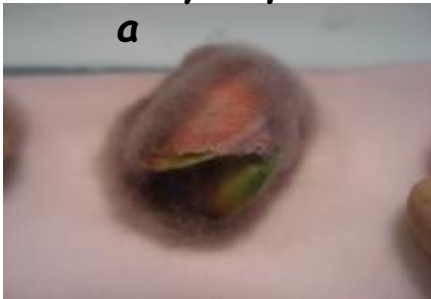
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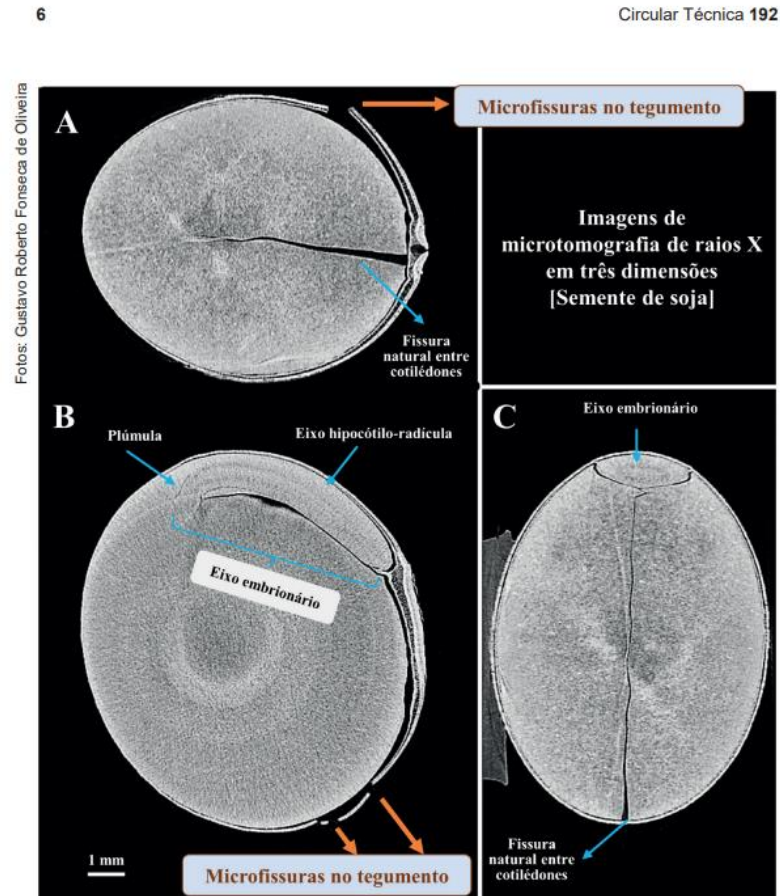
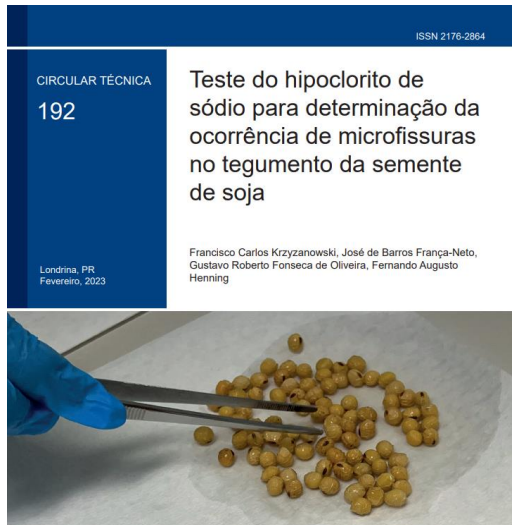
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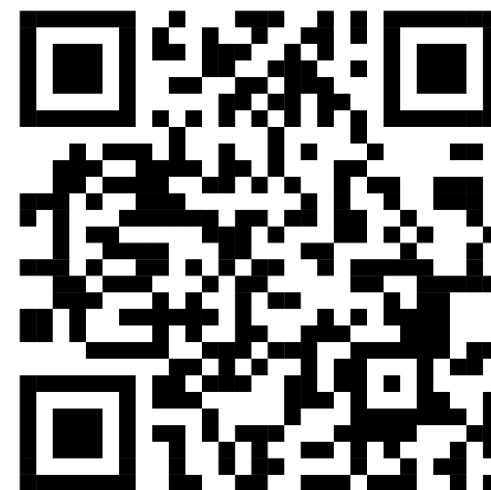
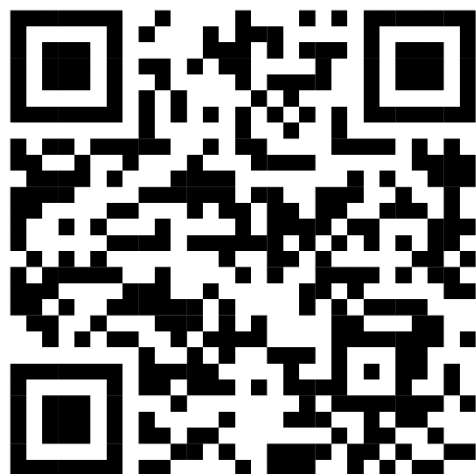
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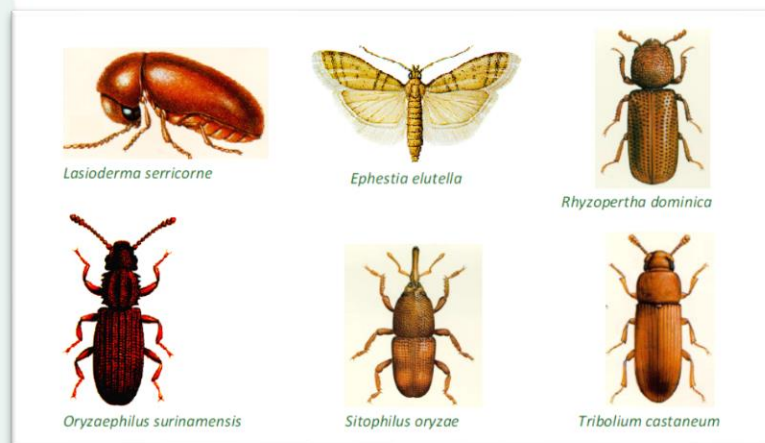


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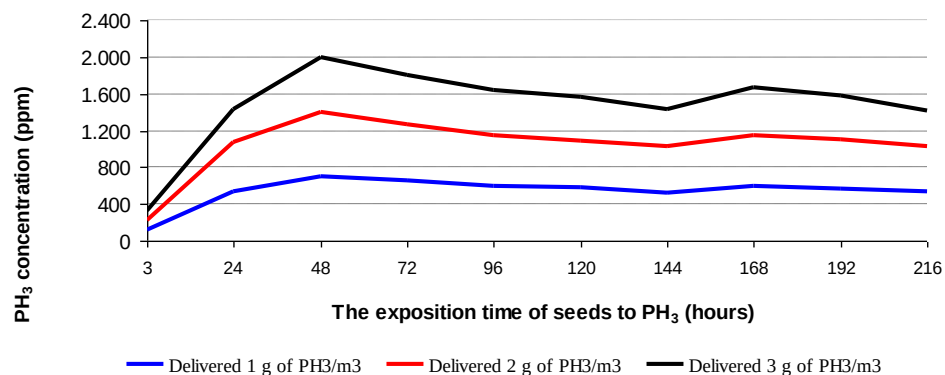
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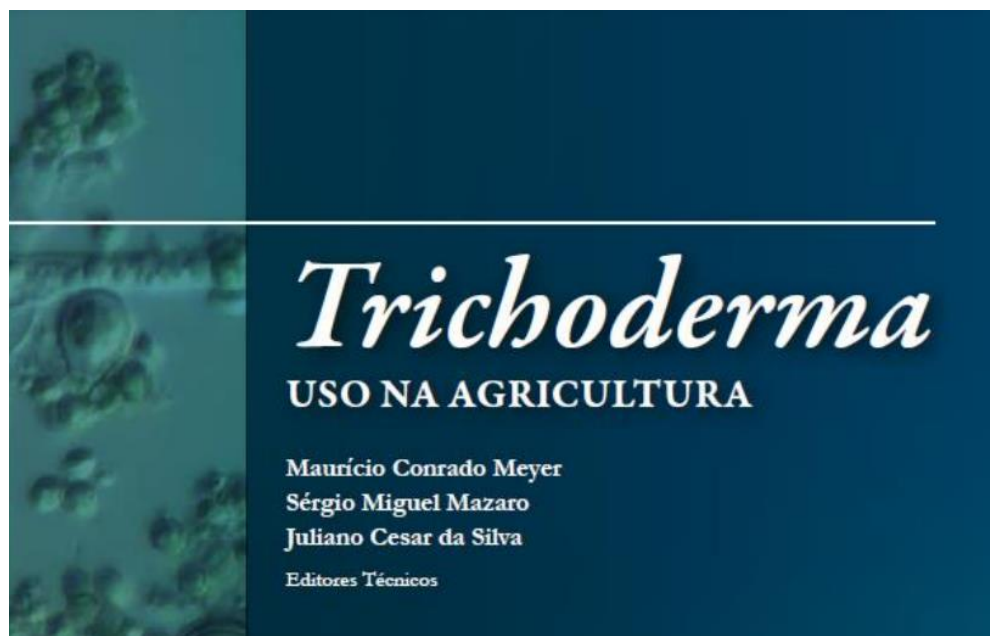
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Muito Obrigado!
Muchas Gracias!
Thank you!

Fernando Henning

fernando.henning@embrapa.br





SOYBEAN

Soil Fertility Management and Mineral Nutrition of Plants

Fábio Alvares de Oliveira
Embrapa Soybean

Londrina, 17th SEP 2024



MINISTÉRIO DA
AGRICULTURA E
PECUÁRIA



Soil Management for Soybean High Yields

REQUIREMENTS

1. Knowledge of soil properties – Chemical – Physical – Biological
2. Historical of agricultural use of the soil
 - Tillage system; potential yield; chemical management
3. Climate conditions – Agricultural Climatic Risk Zoning;
4. Systematic evaluation of soil properties – Soil Chemical analysis
5. Soil amendments and fertilizer management;
6. Evaluation of nutritional status of plants.

Soil Management for Soybean High Yields

BEST PRACTICES OF SOIL MANAGEMENT

1. Soil acidity amendment

Main goal – Reduce chemical limitations (pH and Al^{3+})

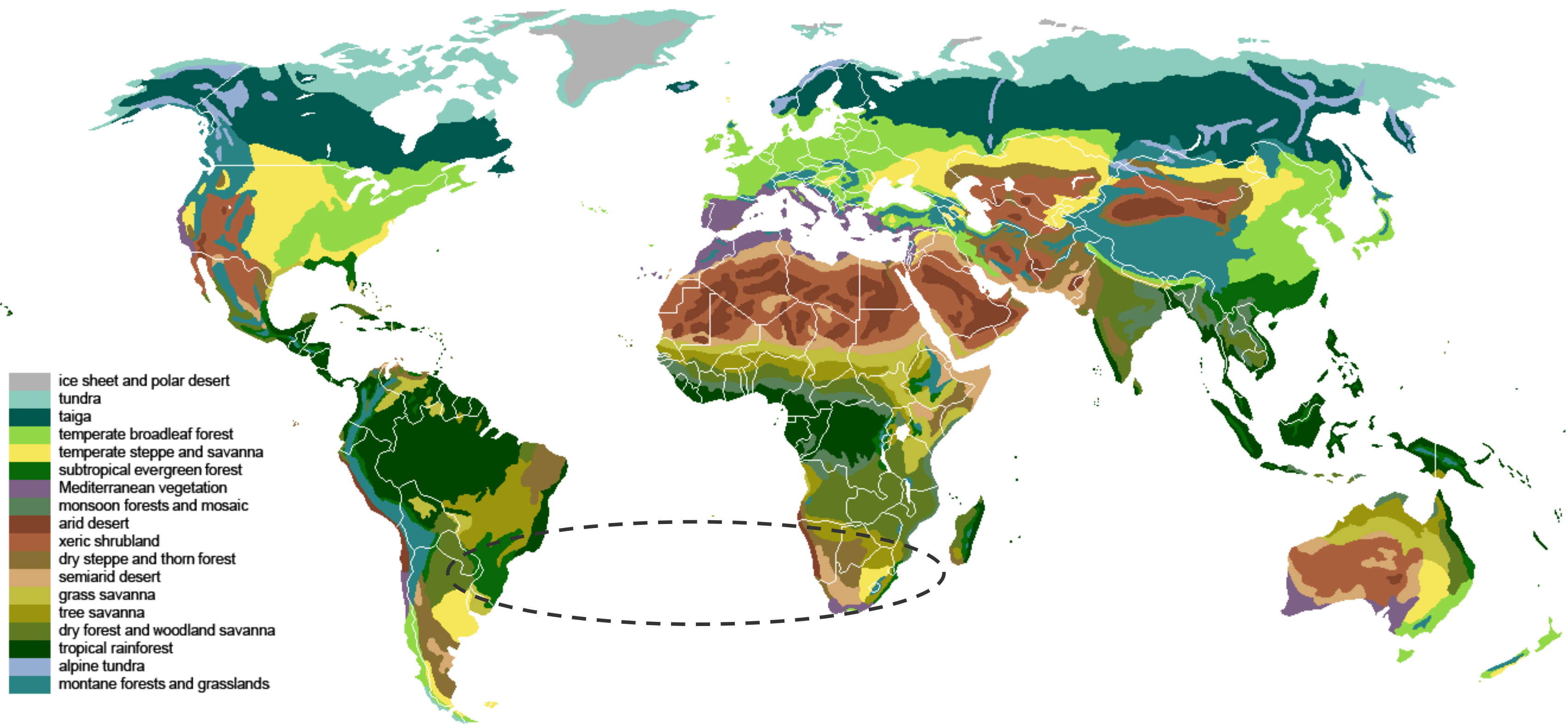
- Increase Ca^{2+} and Mg^{2+} soil contents
- Promote root development

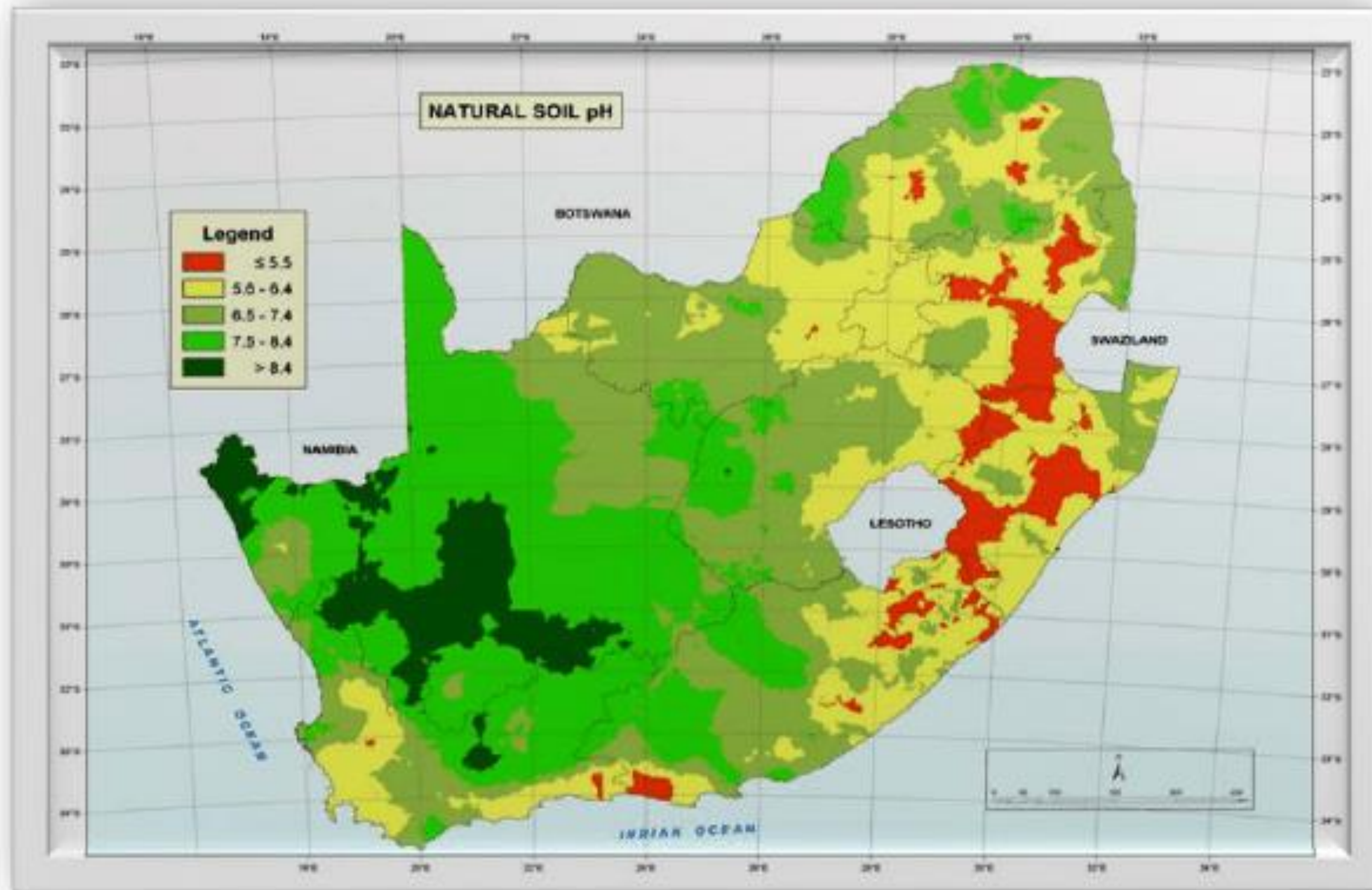
2. Fertilizer management

Main goal – Improve nutrient availability levels

Essential – Phosphorus (P) and Potassium (K)







Source: Soil, Water and Climate of the Agricultural Research Council, South Africa

Soil Fertility Assessment



EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária
Centro Nacional de Pesquisa de Soja - Embrapa Soja
Laboratório de Análise de Solo e Tecido Vegetal - LASTV
RESULTADO DE ANÁLISE DE SOLO

SOLICITANTE:DATA DA COLETA.

Nº LAB.	AMOSTRA	PROF.	pH	Al ³⁺	H + Al	Ca ²⁺	Mg ²⁺	K ⁺	SB	CTC	V%	m%	P	C
				cmolc/dm3						%		mg/dm3 g/dm3		
2302093	PG01	0-20	4,99	0,03	4,32	2,28	1,94	0,06	4,28	8,60	50	0,6	0,70	11,24
2302094	PG02	0-20	5,39	0,00	4,10	4,19	2,27	0,58	7,04	11,14	63	0,0	9,78	12,09
2302095	PG03	0-20	4,55	0,13	6,03	2,40	1,56	0,42	4,38	10,42	42	3,0	3,49	14,50
2302096	PG04	0-20	4,02	0,94	6,60	0,43	0,27	0,07	0,77	7,37	10	54,9	1,14	11,78
2302097	PG05	0-20	4,97	0,11	5,99	4,02	2,20	0,14	6,36	12,35	52	1,7	26,87	17,29

Can I improve the nutrient use efficiency?



RESULTADO DE ANÁLISE QUÍMICA DA TERRA

BÁSICA

ELEMENTOS	TEOR	NÍVEL DE SUFICIÊNCIA		
		BAIXO	MÉDIO	ALTO
Calcio (Ca ²⁺)	1,90			
Magnésio (Mg ²⁺)	0,50			
Potássio (K ⁺)	0,11			
Sódio (Na ⁺)	***			

REAÇÃO DO SOLO

DETERMINAÇÃO	ÍNDICE	ELEMENTOS	TEOR
pH em CaCl ₂	4,46	Alumínio (Al ³⁺)	0,59
pH em SMP	5,89	Acidez Potencial (H + Al)	5,39
pH em H ₂ O	5,19	Acidez Não Trocável (H ⁺)	4,80

ÍNDICES DE SATURAÇÃO

Ca %	24,09
Mg %	6,29
K %	1,34
Na %	***
H %	60,86
Al %	18,94

LEGENDA

EQUILIBRADO

LIMITE DE TOLERÂNCIA

DESEQUILÍBRIO

EXCESSIVO

CAPACIDADE TAMPÃO

Disponibilidade	Fósforo (P)	Enxofre (SO ₄ ²⁻)	Zinco (Zn)
Nível Crítico (mg/dm ³)	***	***	***
Valor Relativo (%)	***	***	***

DOSES PARA RESTITUIR O EQUILÍBRIO DE SATURAÇÃO

cmol _c /dm ³	MÍNIMO	MÁXIMO
Potássio (K ⁺)	0,13	0,29
Calcio (Ca ²⁺)	2,04	3,23
Magnésio (Mg ²⁺)	0,29	1,08

MICRONUTRIENTES

ELEMENTOS	TEOR	NÍVEL DE SUFICIÊNCIA		
		BAIXO	MÉDIO	ALTO
Manganês (Mn)	18,12			
Ferro (Fe)	53,13			
Cobre (Cu)	1,13			
Zinco (Zn)	2,94			
Boro (B)	***			

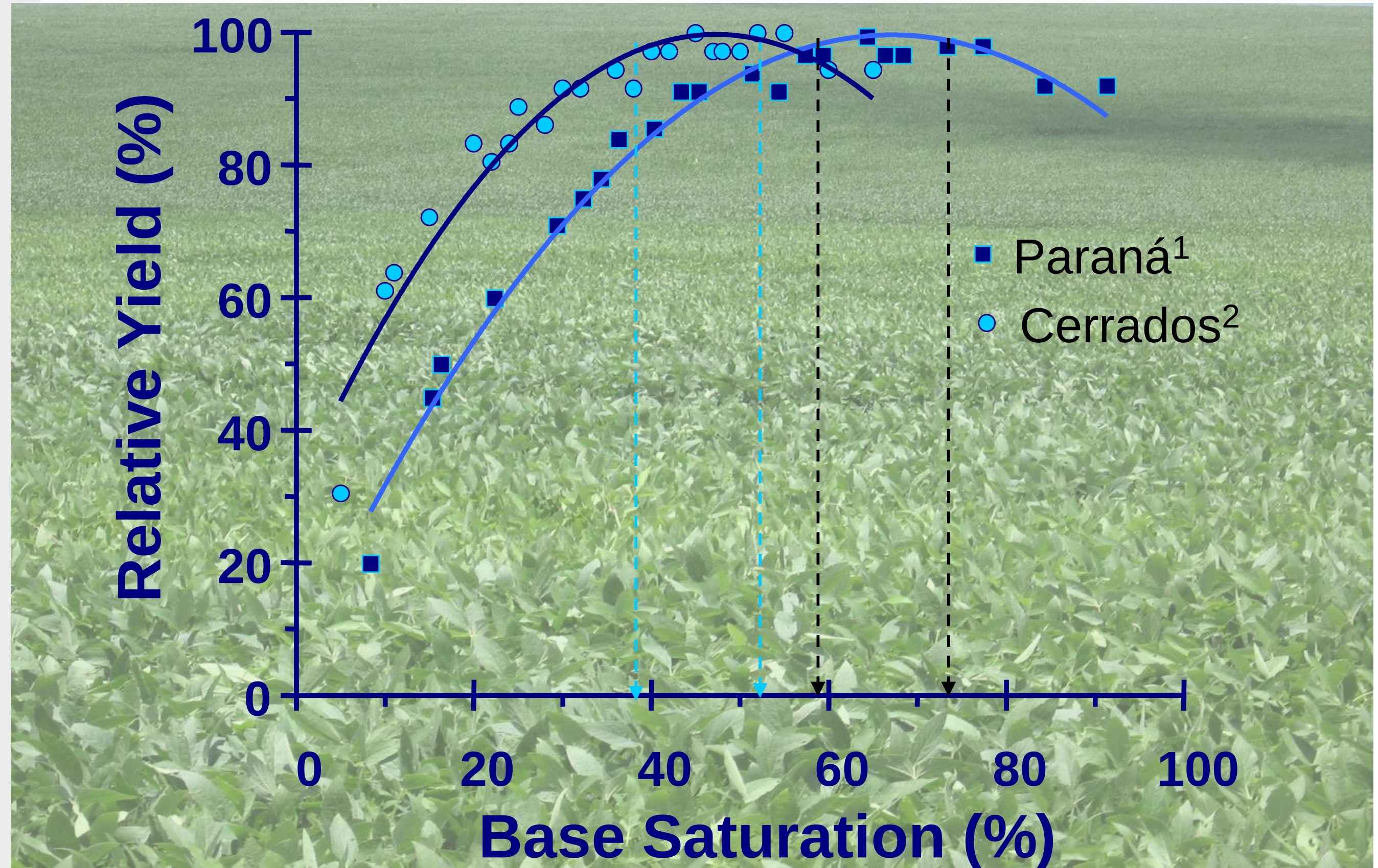
EXTRATORES

(P, K ⁺ , Na ⁺).(SO ₄ ²⁻)	MEHLICH-I;CH3COONH4
(Ca ²⁺ , Mg ²⁺ , Al ³⁺)	KCl 1N
(Mn, Fe, Cu, Zn).(B)	MEHLICH-I; ***

PARA SIMPLES VERIFICAÇÃO PELO SOLICITANTE. NÃO TEM VALOR OFICIAL.

Os dados deste documento HTML, foram arquivados no Laboratório. Qualquer alteração nos dados pode ser detectada.

Liming response



Source: ¹ Embrapa Soja (1999); ²Sousa et al. (2002)

LIME - RESIDUAL EFFECTS 3 – 5 YEARS

4 Rights Nutrient Stewardship Practices



Right Source

Matches fertilizer type to crop needs.

- All fertilizer sources applied have guaranteed or known analysis
- Use controlled, slow-release or stabilized nitrogen blends
- Apply secondary and micronutrients based on soil and tissue tests



Right Time

Make nutrients available when crops need them.

- Split-apply [nitrogen](#) to increase availability
- No phosphorus applied to frozen or snow-covered soils
- Apply fall nitrogen when soil temperatures are consistently below 50 degrees at a 4-inch depth



Right Rate

Matches amount of fertilizer type to crop needs.

- Perform a nutrient budget to account for all inputs and harvest removal
- Utilize regular soil sampling to determine fertilizer rates
- Use variable-rate applications based on grid sampling



Right Place

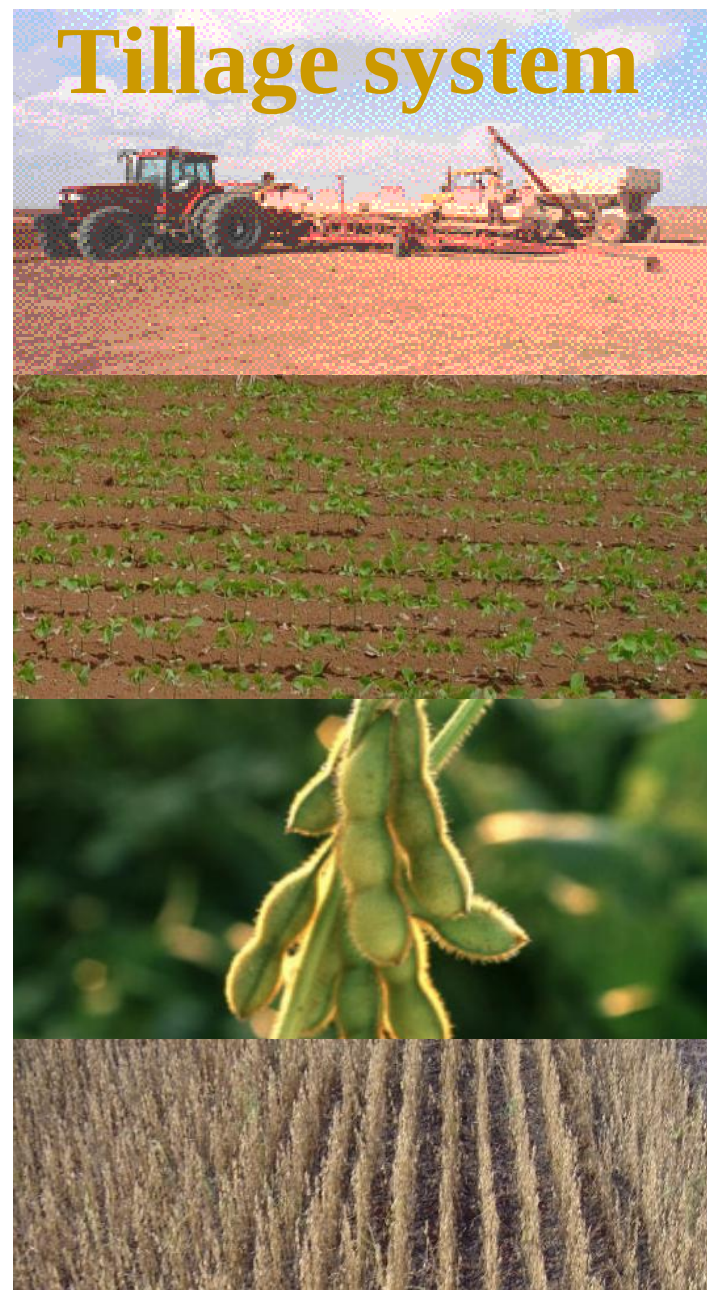
Keeps nutrients where crops can use them.

- Manage fields based on zone maps
- Use precision guidance technology for accurate applications
- Incorporate broadcast-applied phosphorus fertilizers

<https://4rplus.org/nutrient-management/>

Right Fertilization Rate – Framework

- ✓ Nutrient crop exportation;
- ✓ Soil fertility state;
- ✓ Return on investment



Grains



Exportation



Nutritional requirements

Soybean - Extration x Exportation

Shoot parts	Nutrient										
	N	P ₂ O ₅	K ₂ O	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	<i>----- kg/t of grains -----</i>						<i>----- g/t of grains -----</i>				
Grains	54	11	22	2,8	2,5	2,8	31	11,5	65	39	41
Crop residues	24	4,6	36	19,3	8,2	1,4	51	8,3	310	159	34
Extration	78	15,6	58	22,1	10,7	4,2	82	19,8	375	198	75
% Exportation	69	71	38	13	23	67	38	58	17	20	55

Fonte: (Oliveira Junior et al., 2020)



Soil testing results and Regional interpretation



Phosphorus Fertilization for soybean in Parana State

<u>Level</u>	<u>P^{\1}</u>	<u>Rate</u> <u>P₂O₅</u>	<u>P^{\1}</u>	<u>Rate</u> <u>P₂O₅</u>	<u>P^{\1}</u>	<u>Rate</u> <u>P₂O₅</u>	<u>P^{\1}</u>	<u>Rate</u> <u>P₂O₅</u>
	<i>mg/dm³</i>	<i>kg/ha</i>	<i>mg/dm³</i>	<i>kg/ha</i>	<i>mg/dm³</i>	<i>kg/ha</i>	<i>mg/dm³</i>	<i>kg/ha</i>
<u>CEC (cmol_c/dm³)</u>	<u>< 4</u>		<u>4 - 8</u>		<u>8 - 12</u>		<u>12 - 16</u>	
<u>Very low</u>	< 6,0	130	< 5,0	150	< 4,0	160	< 3,0	180
<u>Low</u>	6,0 – 14,0	100	5,0 – 10,0	120	4,0 – 8,0	130	3,0 – 5,0	150
<u>Medium</u>	14,1– 20,0	80	10,1 – 16,0	90	8,1 – 12,0	100	5,1 – 8,0	110
<u>High</u>	20,1 – 40,0	M	16,1 – 32,0	M	10,1 – 18,0	M	8,1 – 15,0	M
<u>Very High</u>	> 40,0	R	> 32,0	R	> 18,0	R	> 15,0	R

^{\1} Labile Phosphorus (Mehlich-1).

Source: Embrapa Soja (2024).



Soil testing results and Regional interpretation



Potassium Fertilization for soybean in Parana State

<u>Level</u>	K^{V1}	Rate K_2O	K^{V1}	Rate K_2O	K^{V1}	Rate K_2O	K^{V1}	Rate K_2O
	<u>$cmol_c/dm^3$</u>	<u>kg/ha</u>	<u>$cmol_c/dm^3$</u>	<u>kg/ha</u>	<u>$cmol_c/dm^3$</u>	<u>kg/ha</u>	<u>$cmol_c/dm^3$</u>	<u>kg/ha</u>
<u>CEC ($cmol_c/dm^3$)</u>	<u>< 4</u>		<u>4 - 8</u>		<u>8 - 12</u>		<u>12 - 16</u>	
<u>Very low</u>	< 0,04	140	< 0,06	180	< 0,09	220	< 0,13	240
<u>Low</u>	0,04–0,08	120	0,07–0,11	160	0,10–0,18	180	0,13–0,26	200
<u>Medium</u>	0,09– <u>0,12</u>	90	0,12– <u>0,22</u>	130	0,19– <u>0,32</u>	150	0,27– <u>0,41</u>	160
<u>High</u>	0,13–0,24	M	0,23–0,44	M	0,33–0,64	M	0,42–0,82	M
<u>Very High</u>	> 0,24	R	> 0,44	R	> 0,64	R	> 0,82	R

^{V1} Exchangeable Potassium (Mehlich-1).

Source: Embrapa Soja (2024).

Nutritional disorders in Soybeans



Foto: Cesar de Castro



Phosphorus deficiency



MACRONUTRIENTES	
ELEMENTOS	RESULTADOS
POTENCIAL DE NEUTRALIZACAO	
PH em CaCl ₂	4,60
PH em H ₂ O	5,10
PH em SMP	5,85
g/dm ³	
MATERIA ORGANICA (M.O.)	20,36
CARBONO (C)	11,81
mg/dm ³	
FOSFORO REMANESCENTE (P-Rem.)	17,73
FOSFORO (P)	3,51
cmol/dm ³	
POTASSIO (K ⁺)	0,50
CALCIO + (Ca ²⁺ + Mg ²⁺)	7,40
MAGNESIO	5,44
CALCIO (Ca ²⁺)	1,96
MAGNESIO (Mg ²⁺)	5,55
HIPOGENIO (H ⁺ + Al ³⁺)	5,30
ALUMINIO	0,25
ACIDEZ TOTAL (H ⁺)	7,90
ALUMINIO (Al ³⁺)	13,45
cmol/dm ³	
SOMA DE BASES (SB)	13,45
CAPACIDADE DE TROCA (CTC)	

MACRONUTRIENTES	
ELEMENTOS	RESULTADOS
POTENCIAL DE NEUTRALIZACAO	
PH em CaCl ₂	5,00
PH em H ₂ O	5,70
PH em SMP	6,10
g/dm ³	
MATERIA ORGANICA (M.O.)	19,23
CARBONO (C)	11,15
mg/dm ³	
FOSFORO REMANESCENTE (P-Rem.)	20,53
FOSFORO (P)	6,18
cmol/dm ³	
POTASSIO (K ⁺)	0,42
CALCIO + (Ca ²⁺ + Mg ²⁺)	11,40
MAGNESIO	8,44
CALCIO (Ca ²⁺)	2,96
MAGNESIO (Mg ²⁺)	4,61
HIPOGENIO (H ⁺ + Al ³⁺)	4,61
ALUMINIO	0,00
ACIDEZ TOTAL (H ⁺)	11,82
ALUMINIO (Al ³⁺)	16,43
cmol/dm ³	
SOMA DE BASES (SB)	16,43
CAPACIDADE DE TROCA (CTC)	



Potassium deficiency





1450 ha

Conclusions

- Soybean yield potential is dependent of high soil quality: chemical, physical and biological;
- It's essential to diagnosis and correct the yield limiting factors;
- The acidity management benefits the nutrient availability in tropical soils;
- Apply the 4Rs stewardship best practices;
- Major attention to Phosphorus and Potassium management;
- Monitoring soil fertility and nutritional status of plants.

Thank you!

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