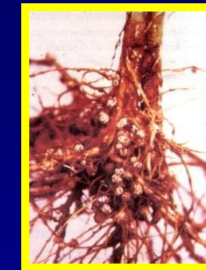
# Microorganisms for agricultural and livestock systems: The “micro” green revolution has started !!!

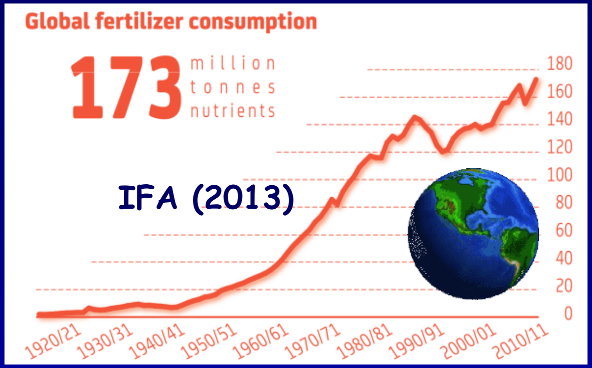


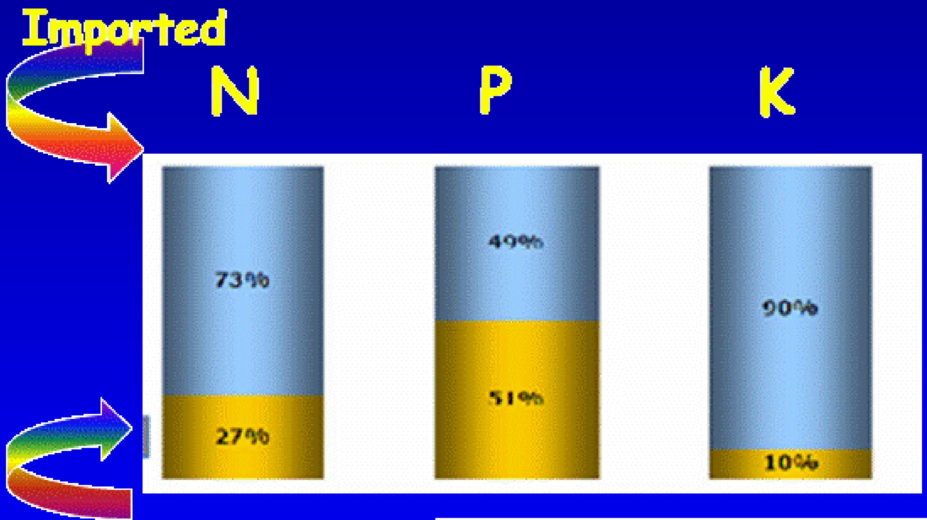
# Microrganismos para sistemas agropecuários: A “micro” revolução verde começou!!!

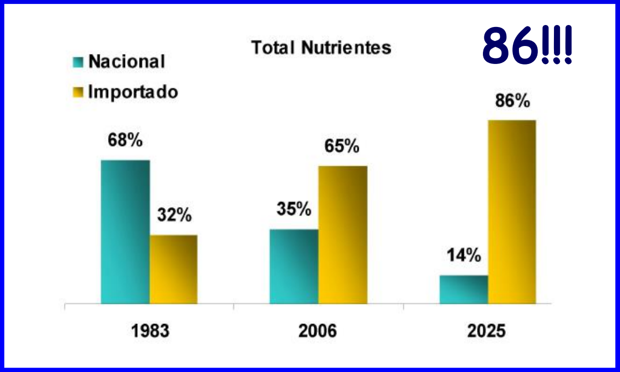

***Mariangela Hungria***

*mariangela.hungria@embrapa.br*

# Plants need nutrients



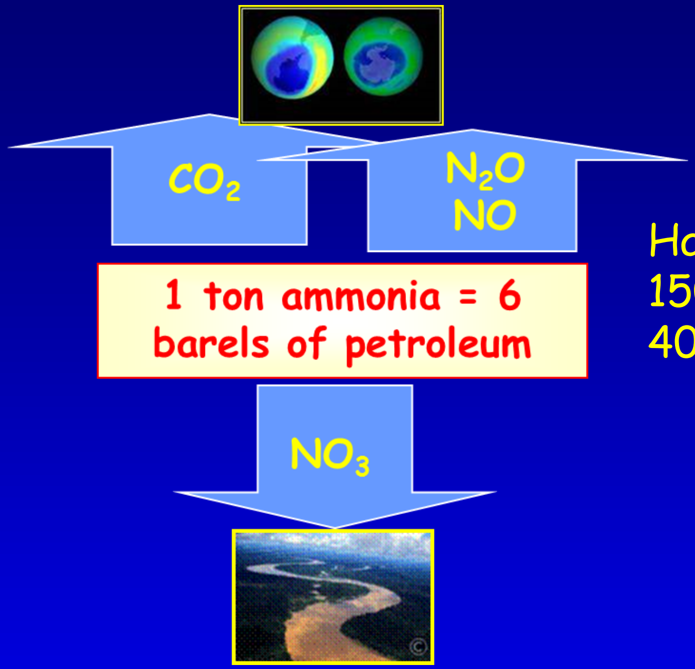




- There are microorganisms that can partially or fully supply plants' requirements of some nutrients

- N is the nutrient most demanded by plants

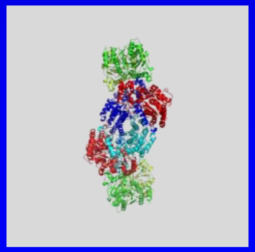
1 kg N ~ 10 kg e-$CO_2$

- Pollution by N-fertilizers is dramatic




Haber-Bosch
150-250 atm
400-500 °C

- Biological nitrogen fixation is probably the most sucessful example of contribution of microorganisms to plant nutrition



nitrogenase

- Agriculture requires selection (indigenous crops) or “breeding” (exotic crops) of microorganisms, to be introduced as “elite” strains

Soybean is nitrogen !!!!!

Soybean plays an increasing role as protein source

>10% in "low-income food-deficit countries"

Modern genotypes ~ 80 kg of N per 1,000 kg of grains

- 3000 kg/ha ~240 kg of N/ha, but 50% is lost - 480 kg N/ha

# Biological nitrogen fixation with soybean in Brazil

- 50 years of research !!!!

Inoculated

Cerrados, 1970s

Non-inoculated

- Nowadays, reinoculation

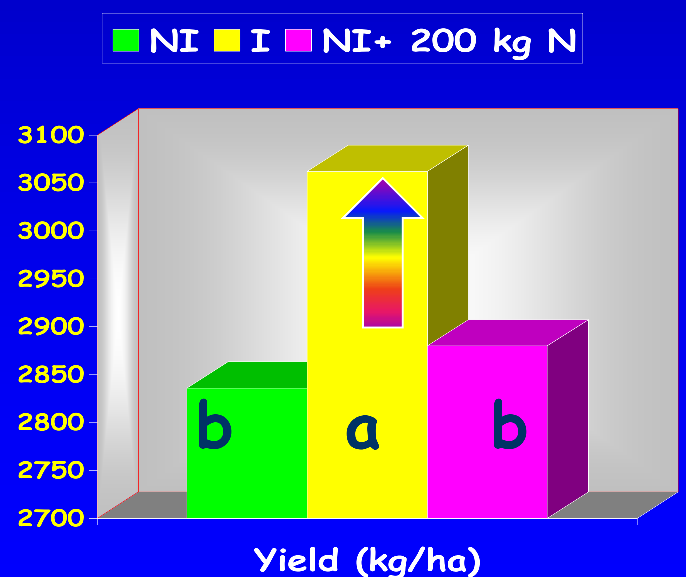
> 20 years, > 300 trials

Soils with $10^3$ to $10^6$ cells/g soil

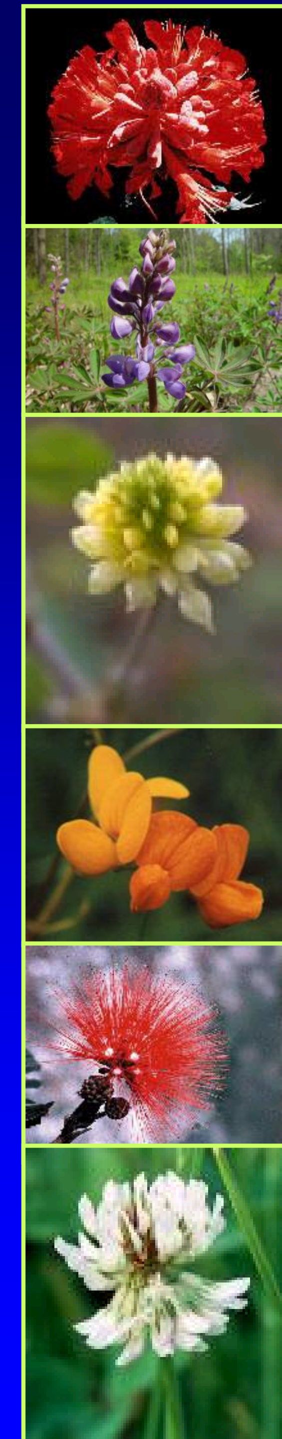
Yields >2,000 kg/ha

+ 8%

($p$<0.05)




- Worldwide, breeding has allowed genetic gains of 1% per year!!!



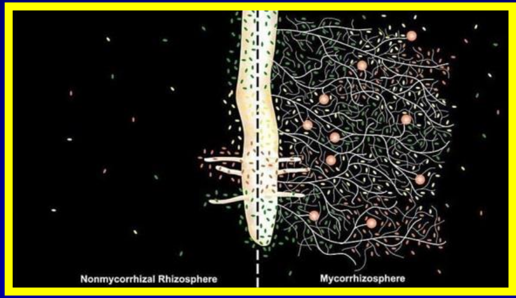
kg N/ha

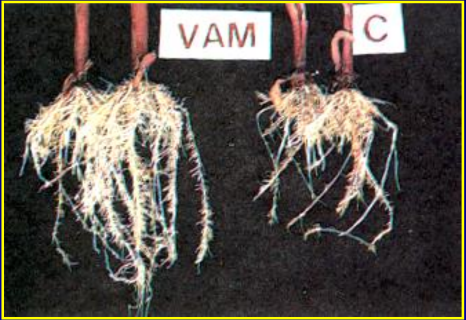
| | | |
|---|---|---|
| *Acacia spp.* | acacia | 5-50 |
| *Arachis hypogaea* | groundnut | 32-206 |
| *Cajanus cajan* | pigeonpea | 68-88 |
| *Calopogonium muconoides* | calopogonium | 64-182 |
| *Centrosema spp.* | centrosema | 41-280 |
| *Cicer arietinum* | chickpea | 0-141 |
| *Desmodium spp.* | desmodium | 25-380 |
| *Gliricida sepium* | gliricida | 26-75 |
| *Glycine max* | soybean | 0-450 |
| *Lathyrus sativus* | lathyrus | 172-227 |
| *Lens culinaris* | lentil | 5-191 |
| *Leucaena leucocephala* | leucaena | 98-274 |
| *Lupinus albus* | sweet lupin | 40-160 |
| *Lupinus angustifolius* | lupin | 19-327 |
| *Lupinus mutabilis* | bitter lupin | 95-527 |
| *Macroptilium atropurpureum* | siratro | 46-167 |
| *Medicago sativa* | alfalfa | 45-470 |
| *Melilotus officinalis* | yellow sweet clover | 84 |
| *Neonotonia wightii* | perennial soybean | 126 |
| *Phaseolus vulgaris* | common bean | 0-165 |
| *Pisum sativum* | field pea | 4-244 |
| *Pueraria phaseoloides* | tropical kudzu | 115 |
| *Sesbania spp.* | sesbania | 7-109 |
| *Stylosanthes spp.* | stylosanthes | 4-263 |
| *Trifolium spp.* | clover | 67-260 |
| *Vicia benghalensis* | vetch | 125-147 |
| *Vicia faba* | faba bean | 12-330 |
| *Vigna mango* | black gram | 119-140 |
| *Vigna radiata* | green gram | 58-107 |
| *Vigna unguiculata* | cowpea | 9-201 |
| *Zornia glabra* | zornia | 61 |

**We have selected elite strains for almost 100 legumes !!!**

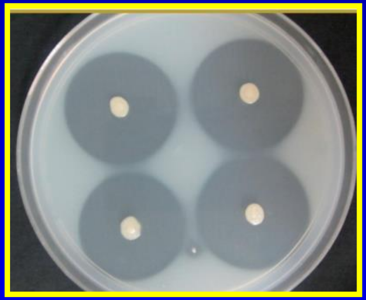
# Phosphorus

- Mycorrhiza fungi can increase plant growth by > 8,000%




- Phosphate solubilizing bacteria



rock

rock + *Bacillus*

# Potassium



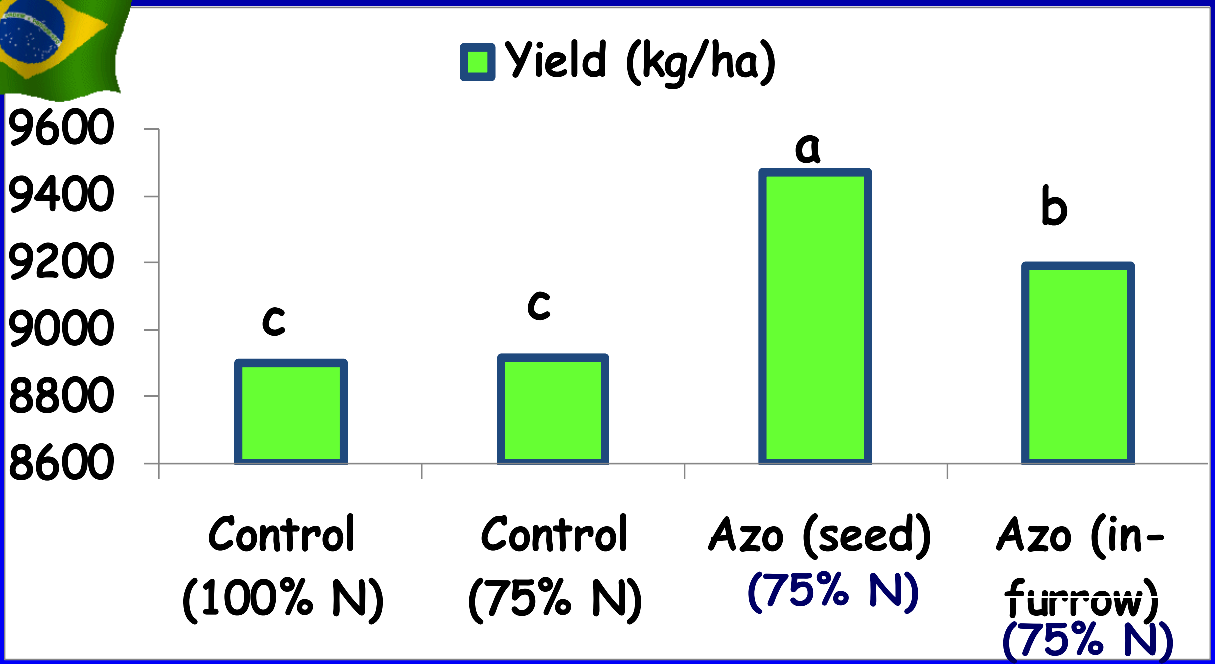
- Rock solubilizers

# Microorganisms may contribute with multiple processes

*Azospirillum brasilense*

Phytohormones + Nitrogen fixation

First commercial inoculant: 2009

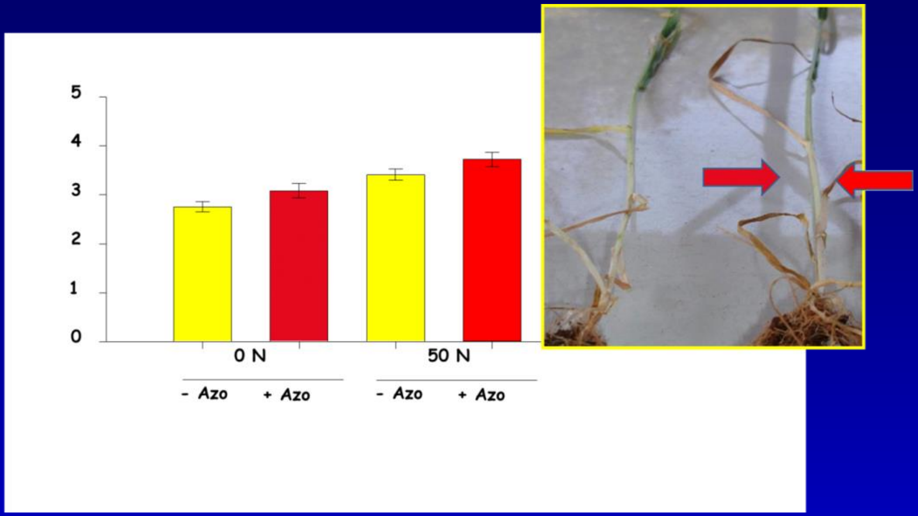



+8.5%

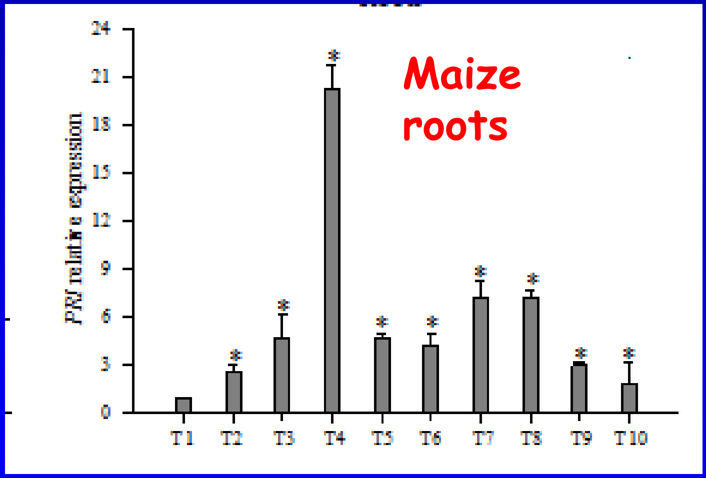
High yields, and increases with 25% less N-fertilizer

Nowadays, 5 million doses of inoculants

## Stem thickness: bedding




## Tolerance to pathogens, and to abiotic stresses




Gene expression – *PR1, PR2, PR4, APX1, APX2; CAT1; SOD2, SOD4*

## Yield + Uniformity

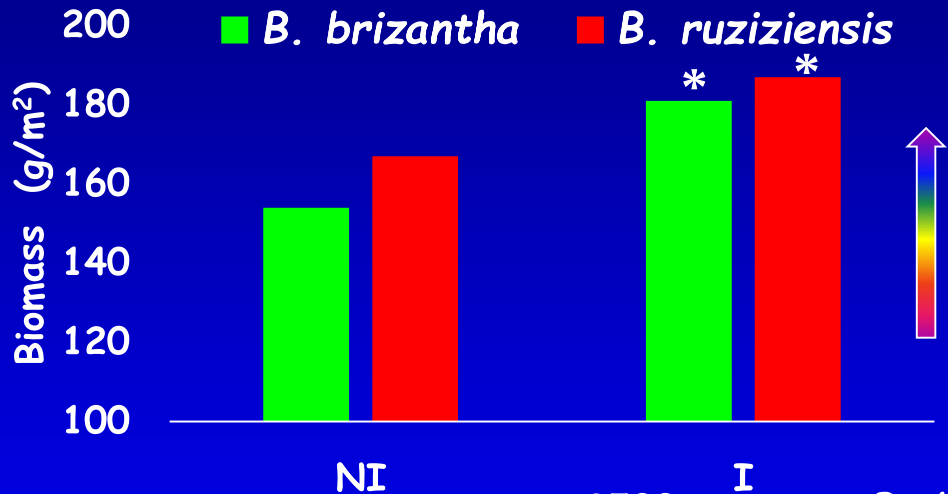
+ Azo

- Azo

# *Brachiaria (=Urochloa) + A. brasilense*

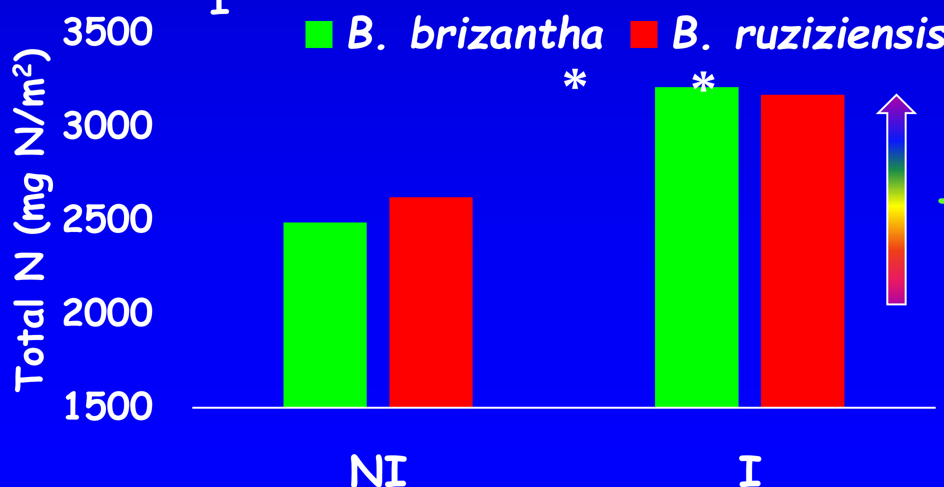
180 million ha pastures, the majority with brachiarias, ~80% in some stage of degradation

Commercial inoculant - 2018




+15% biomass

(with 40 kg N/ha)


+25% protein

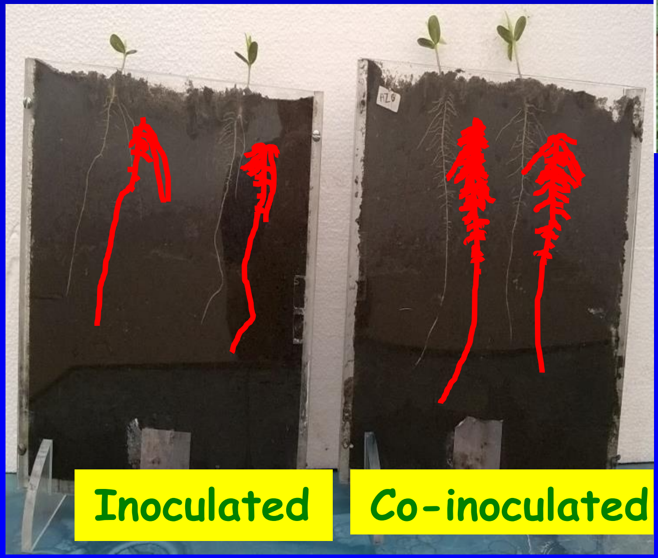
“Vision of Future” is to use cocktails of microorganisms and microbial molecules !!!!!

Recovery of degraded areas:

rhizobia + mycorrhiza

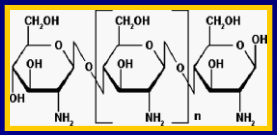
# Co-inoculation of rhizobia + *Azospirillum* (2014)

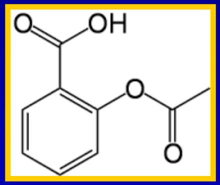
| % increase in yield (kg/ha) - old areas”” | ≠ % |
|---|---|
| *Bradyrhizobium* | 8.4 * |
| *Bradyrhizobium* + *Azospirillum* | 16.1 * |

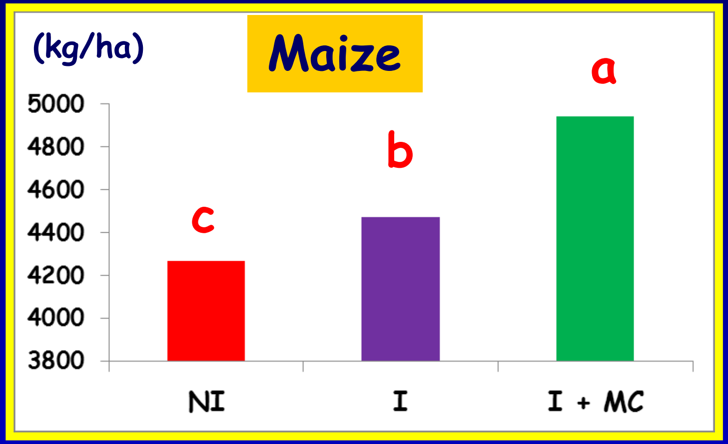



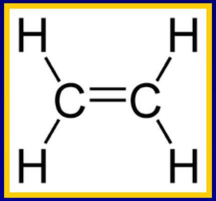

| % increase in yield (kg/ha) | ≠ % |
|---|---|
| *Rhizobium* | 8.3 * |
| *Rhizobium* + *Azospirillum* | 19.6 * |

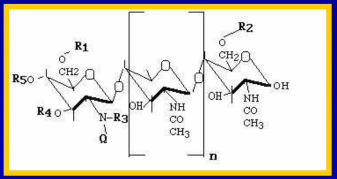
# Microbes + Microbial molecules



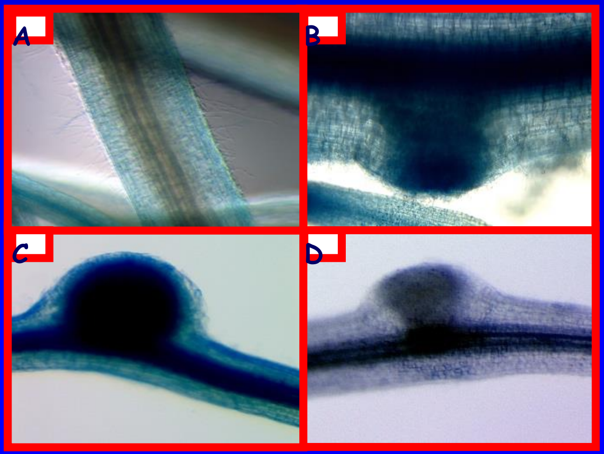


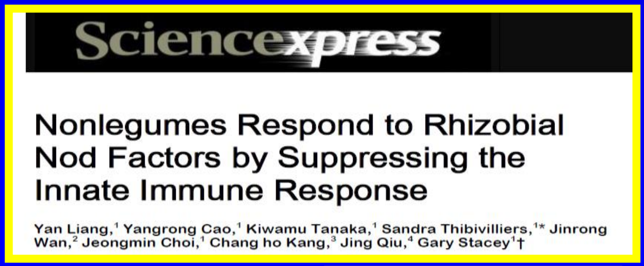




NI – non-inoculated
+ I - *A. brasilense*
Metabolites Concentrated (MC) of *R. tropici*



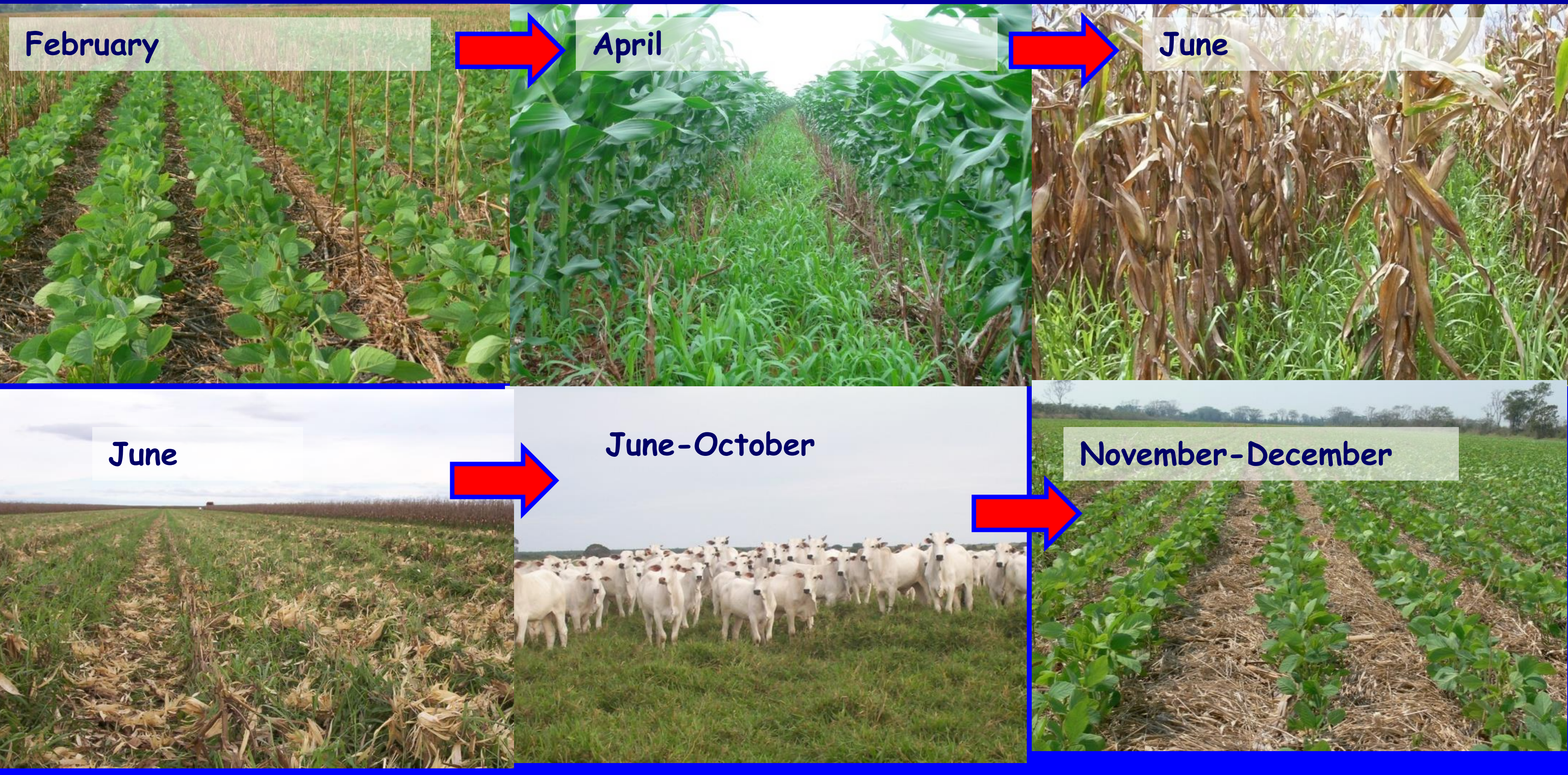


Sciencexpress

Nonlegumes Respond to Rhizobial Nod Factors by Suppressing the Innate Immune Response

Yan Liang,[1] Yangrong Cao,[1] Kiwamu Tanaka,[1] Sandra Thibivilliers,[1*] Jinrong Wan,[2] Jeongmin Choi,[1] Chang ho Kang,[3] Jing Qiu,[4] Gary Stacey[1]†

5 September 2013

“Vision of Future” is to use microorganisms and microbial molecules not for a single crop, but for cropping systems !!!!!



# "Vision of Future" is to use microbes as bioindicators of soil quality

**Londrina**

Physical, chemical parameters, SOM → 8-15 years

Microbiological parameters → 2 years
+ MB-C – 15%
+ MB-N – 18%

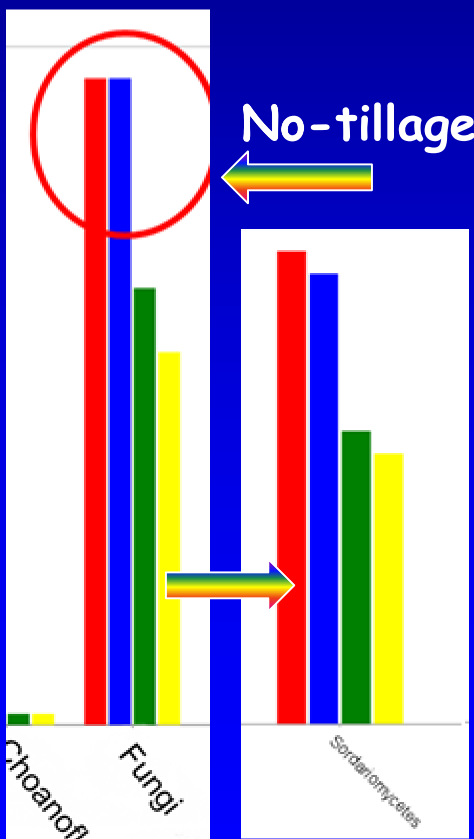
5 years
+ MB-C – 80%
+ MB-N – 104%

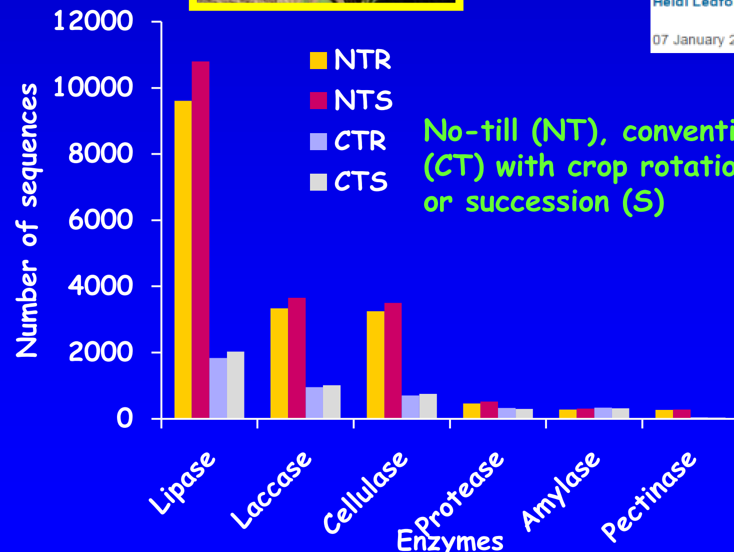
**Cerrado**

| Microbial indicator | Interpretative classes as a function of SOC | | |
|---|---|---|---|
| | Low | Moderate | Adequate |
| No-Tillage | | | |
| MBC | ≤245 | 246–440 | > 440 |
| Arylsulfatase | ≤25 | 26–145 | > 145 |
| Acid phosphatase | ≤700 | 701–1260 | > 1260 |
| β-Glucosidase | ≤90 | 91–225 | > 225 |
| Conventional Tillage | | | |
| MBC | ≤235 | 236–375 | > 375 |
| Arylsulfatase | ≤45 | 46–105 | > 105 |
| Acid phosphatase | ≤660 | 661–940 | > 940 |
| β-Glucosidase | ≤100 | 101–185 | > 185 |

“Vision of Future” is to identify microorganisms to be used as “probes” of quality, new processes, and new enzymes by “omics” approaches

## Metagenome of a soil of Londrina-PR




No-till (NT), conventional till (CT) with crop rotation (R) or succession (S)


nature International weekly journal of science

Home | News & Comment | Research | Careers & Jobs | Current Issue | Archive | Audio & Video

News & Comment > News > 2016 > September > Article

NATURE | NEWS

Promising antibiotic discovered in microbial ‘dark matter’

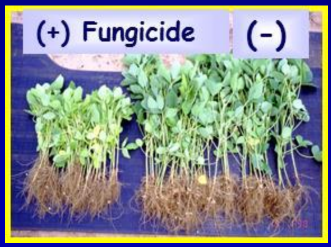
Potential drug kills pathogens such as MRSA — and was discovered by mining 'unculturable' bacteria.

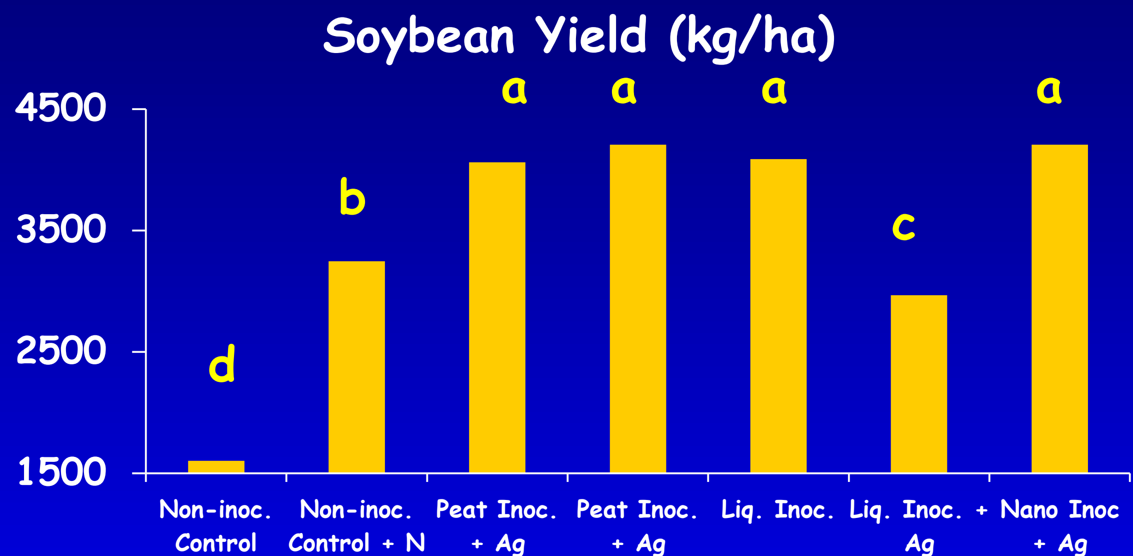
Heidi Ledford

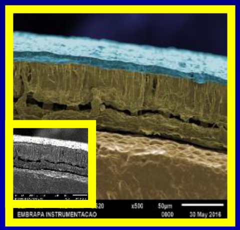
07 January 2015


First new antibiotic in 30 years discovered in major breakthrough

# "Vision of Future" is to innovate in the bioeconomy: nanoinoculants

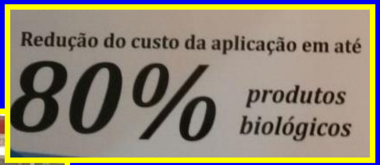


- But taking care of the present, paying atttention to the "real life" (such as N-fertilizer companies, "private" inoculants...)

  - N-fertilizer industry: + 400 trials showing no benefits




# "Vision of Future" is to think about microbial processes as "environmental services"

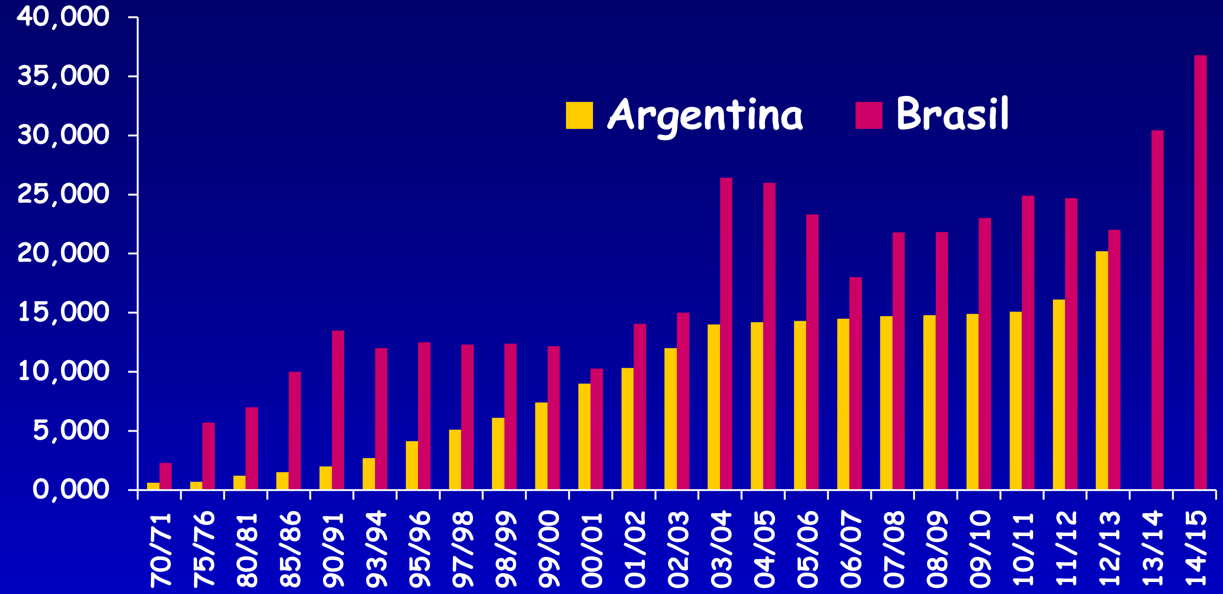
| Crop | Saving of N-fertilizer/hectares | Area (million hectares) | Total N-fertilizer (million ton N) | $CO_2$-e* (million ton) |
|---|---|---|---|---|
| Soybean | 420 kg N/ha | 33 | 13.7 | 62 |
| Brachiaria | 40 kg N/ha | 90 (50%) | 3.6 | 16.2 |
| Common bean | 25 kg N/ha | 3.1 | 0.077 | 0.35 |
| Maize | 20 kg N/ha | 17.5 | 0.35 | 1.58 |

(Considering 1 kg N = 4.5 kg $CO_2$-e/kg de N - the usual value is 10 kg)

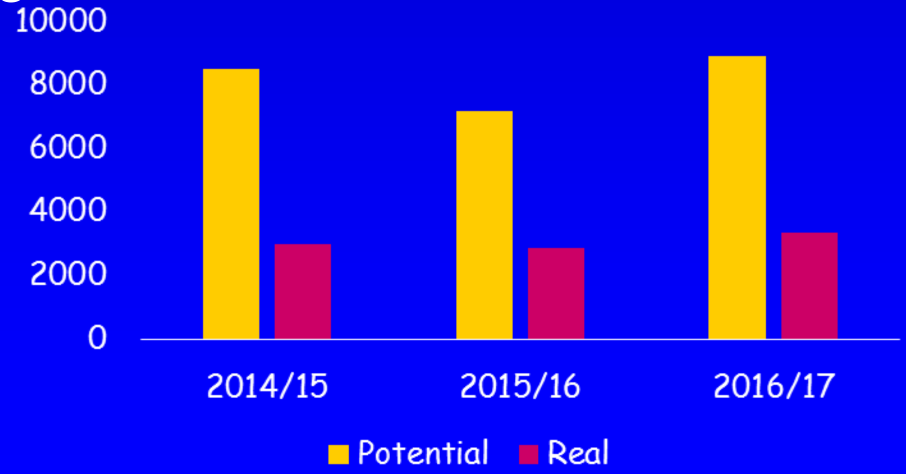
**One year ... four crops ... saving of 80 million tons of $CO_2$-e !!!**

- Farmer's perception about the importance of microorganism is increasing

Doses (million) inoculants commercialized




- A general perception that microorganisms may represent the solution for the the gap between potential and real grain yields




# The reality today is impressive

## Biological nitrogen fixation with soybean

~33.9 million ha, 3,364 kg/ha

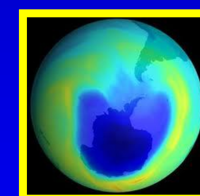
~US$ 13 billion/ye

of $CO_2$-e

**Thank you !!!**

The future... revolution is starting

Higher sustainability to the planet



Higher profit and life quality for the farmer

Economy in chemical fertilizers and improvement in plant and soil health