# Biological Nitrification Inhibition (BNI)-Technology

*Tackling Agricultural Greenhouse Gas Emissions*

# A
# Genetic-Mitigation Strategy


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*JIRCAS, Japan*


*Collaborators & Partners*

**CIAT**

**CIMMYT**

**ICRISAT**

**CCAF**


JIRCAS-NARO International Symposium on
Agricultural Greenhouse Gas Mitigation,
31st August 2017, Tsukuba, Japan


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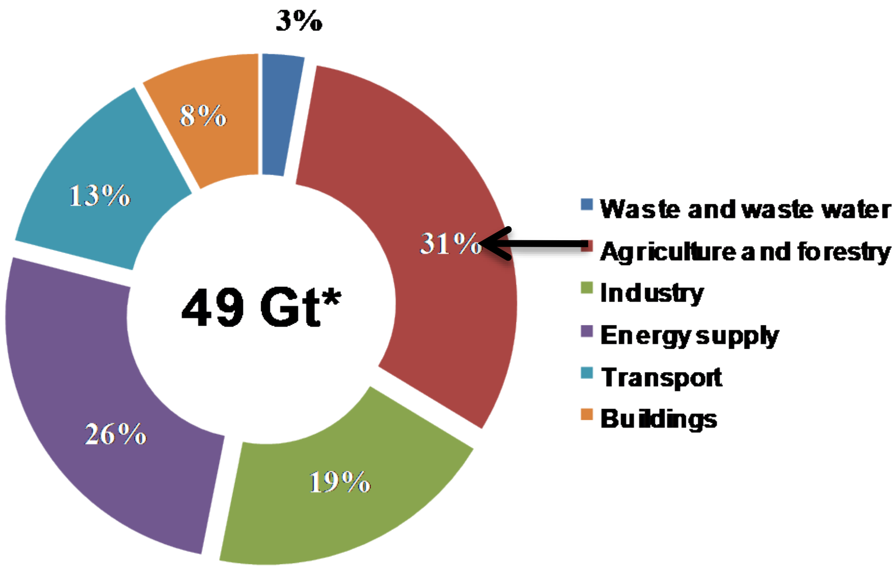
# Global GHG emissions

*Monetization of climate effects using "the best available science and economics"*




***49 Gt of $CO_2$ eq.yr$^{-1}$**

*2004 data; Nature 2011*

1 Gt = 1 billion tons

*IWG = Interagency Working Group on Social cost of GHG*

***Cost of global damage from GHG is***

**\$50 t$^{-1}$ $CO_2$***

**based on IWG recent estimate (Science 2017, 357:655)*

*Cost of Global damage from GHG emissions estimated at*

\$US 2450 billion y$^{-1}$ (\$US 2.45 trillion y$^{-1}$)



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## Agriculture alone is responsible for 14 Gt $CO_2$.eq.$y^{-1}$

*About 24% of total GHG emissions*

**A major portion (80%) of agricultural GHG emissions are associated with**

# Production and Use of N-fertilizers

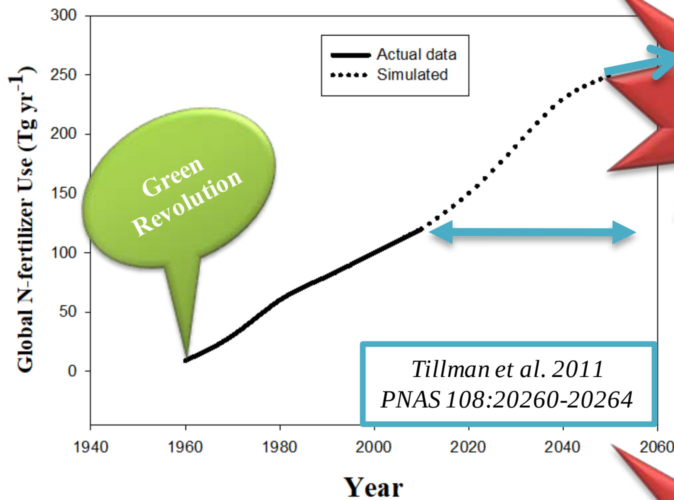
*(based on life-cycle analysis, which is energy and carbon intensive)*

*The social cost of 14 Gt of GHG emissions from agriculture is*

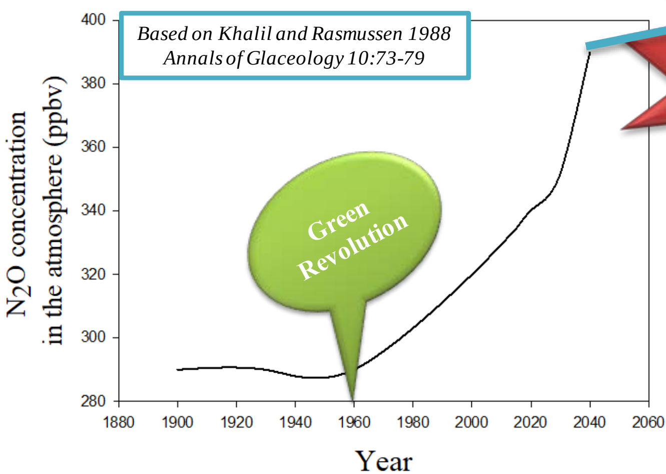
# \$US 700 billion $y^{-1}$

# Global food production has doubled from 1960 – 2000

*Nitrogen fertilizer consumption increased 10-fold*




**N-fertilizer usage to reach 250 Tg yr$^{-1}$**




**$N_2O$ emissions double from 2011 levels**

*Nitrogen fertilizer consumption worldwide in 2010*

**>120 Tg** **(million metric tons)**

*Energy cost of nitrogen fertilizer* – 1.8 to 2 L diesel oil per kg N fertilizer

**1.70 billion barrels of diesel oil**

**(energy equivalent) is needed to produce this nitrogen fertilizer**

**Nearly 70% of the N fertilizer applied is lost to the environment**

*Amounts to a direct annual economic loss of*

**US$ 90 billion***

*[*based on - a) world annual N fertilizer production is 150 million Mg; b) 0.45 US$ kg$^{-1}$ urea]*

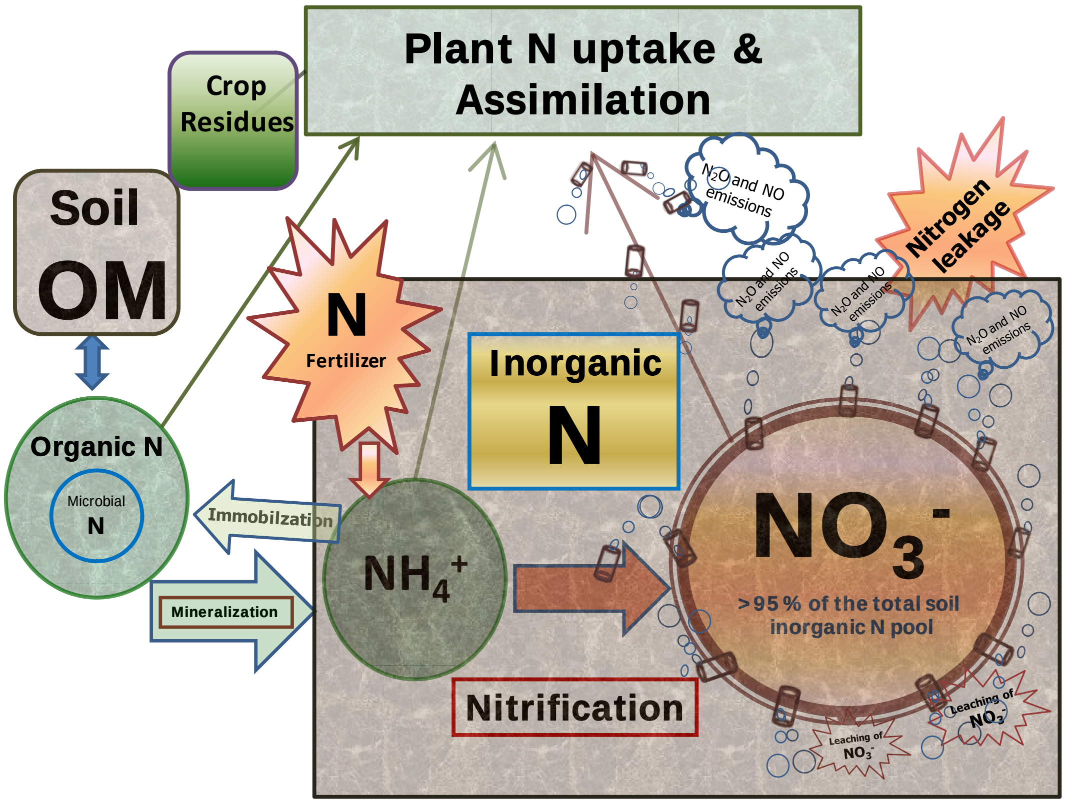
**Why NUE is <30% in most agricultural systems?**

**Uncontrolled rapid nitrification in agricultural soils**

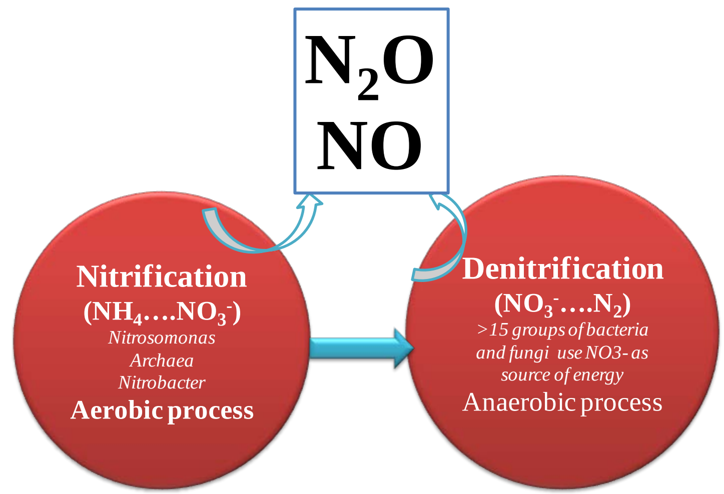
# Nitrification and denitrification

*are the primary drivers for generation of*

# $N_2O$




**>80% of global $N_2O$ emissions**
*is generated from Farming*




**Intensification of agricultural practices led to acceleration of nitrification in modern production systems**

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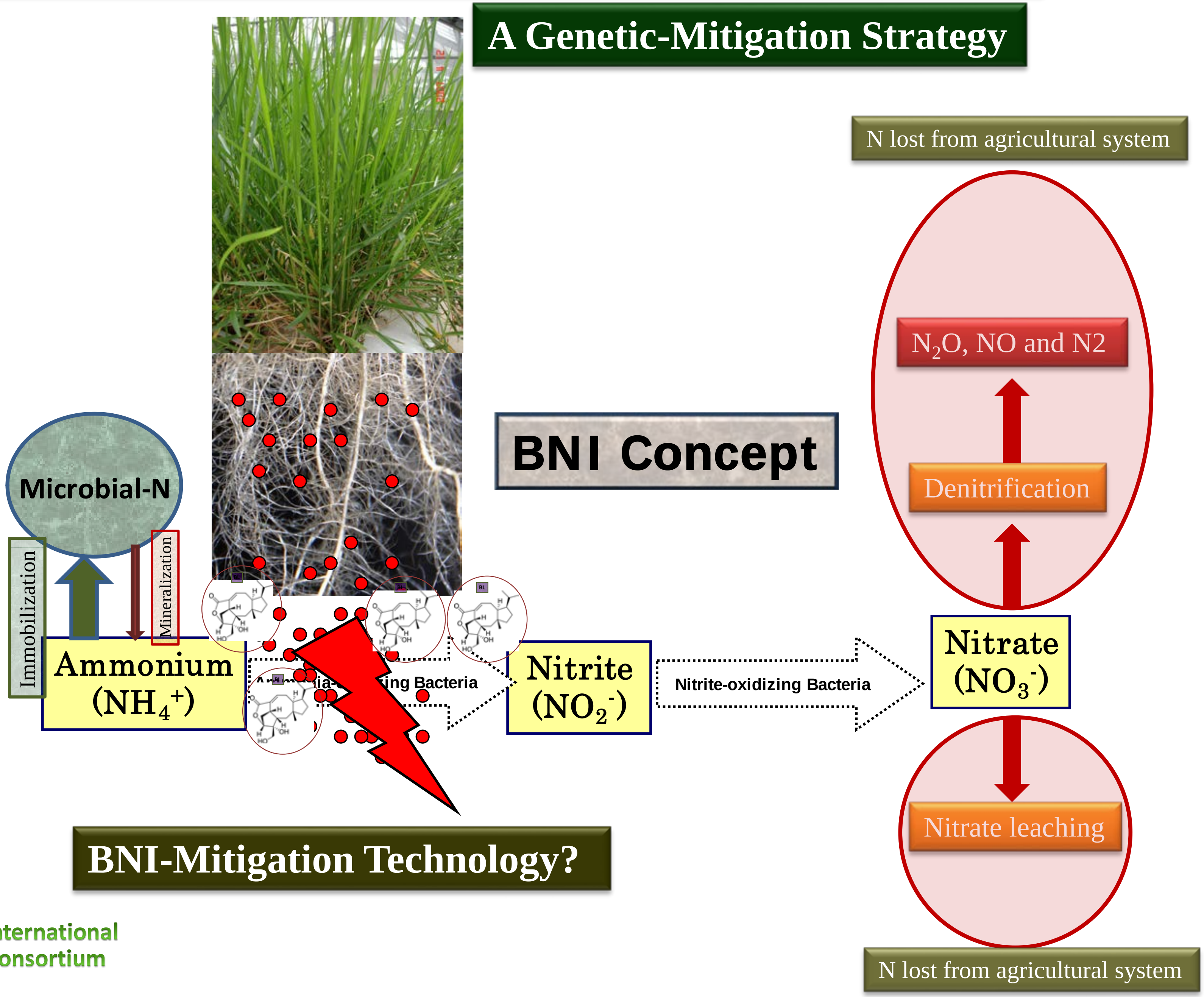
# Switch to low-nitrifying agricultural systems

*How to achieve low-nitrifying agricultural soils?*

# Concept of Biological Nitrification Inhibition (BNI)

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# How to engineer a plant function *into* Technology & Research Strategy

## Characterization of BNI function

- Strength of BNIs production in crops/pastures
- Genetic variability in BNI-trait
- Chemical-identity of BNIs
- How stable are BNIs?
- Soil conditions influence on BNIs functioning
- BNI concentration required in soil to be effective
- Effectiveness in tropics *vs* temperature environs
- Regulatory mechanisms for BNI release
- Mode of inhibitory action
- Negative effects on soil microbial community

**Release rates**

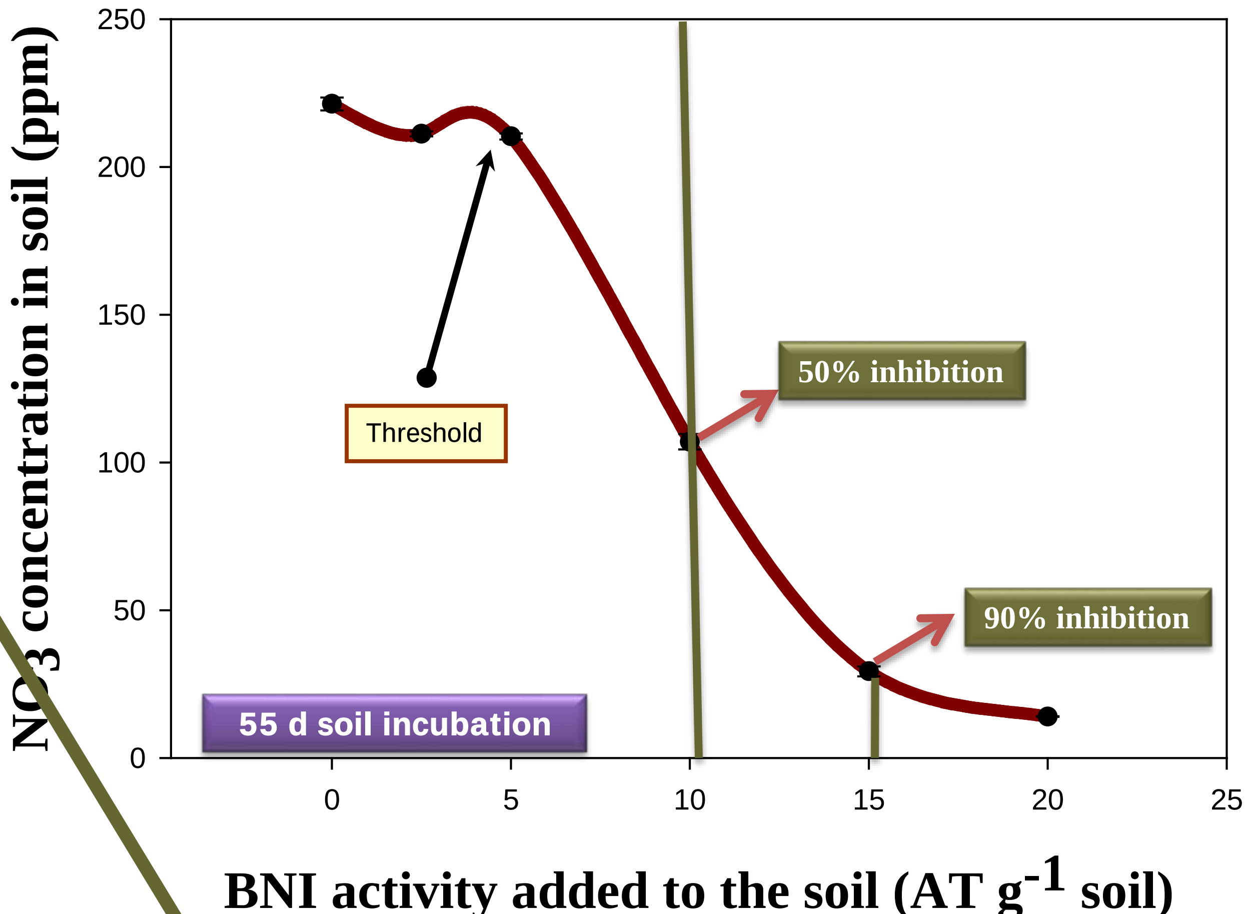
**Stability**

**$ED_{50}$**

*Determines*

**Effectiveness** of BNI function in the field

**BNIs can provide stable inhibitory effect on soil nitrification**




*Releases about 200 to 400 ATU hydrophilic BNI $d^{-1}$*

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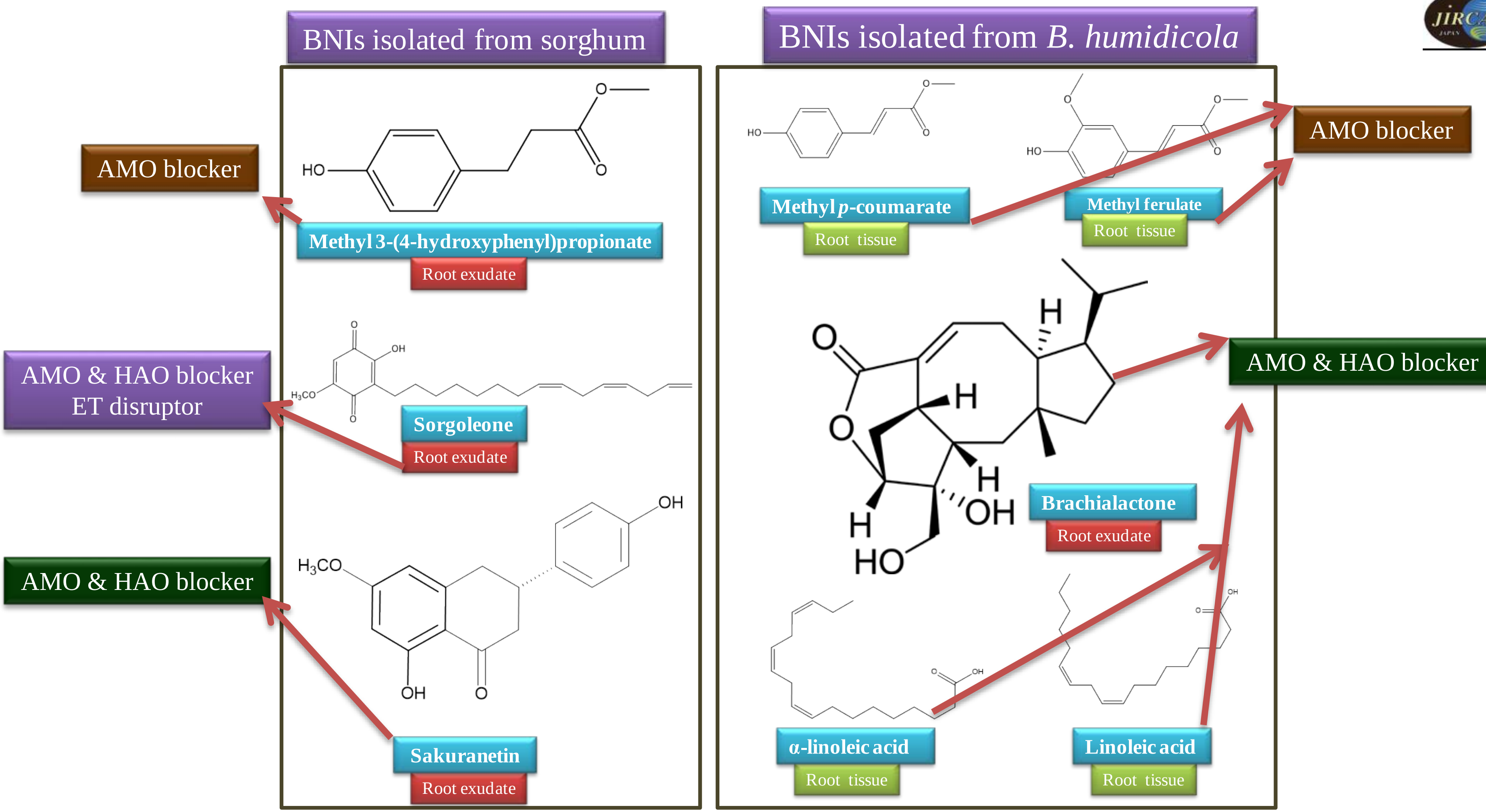
# Plants produce a cocktail of BNIs to suppress nitrifying bacteria *Nitrosomonas*

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# How much BNI-activity is released from root systems of *B. humidicola*?
*An assessment*

*B. humidicola* roots can release 2.6 to 7.5 million BNI activity $d^{-1}$ $ha^{-1}$

- **Active root biomass in a long-term BH pasture being 1.5 Mg $ha^{-1}$**
  - *(Root mass up to 9.0 Mg $ha^{-1}$ has been reported in BH pastures)*
- BNI release rates can be 17 to 50 ATU $g^{-1}$ root dry wt. $d^{-1}$
- Estimated BNI activity release $d^{-1}$ could be 2.6 x $10^6$ to 7.5 x $10^6$ ATU

  **(CIAT 679)** **(CIAT 26159)**
- 1 ATU being equal to 0.6 μg of nitrapyrin
- **This amounts to an inhibitory potential equivalent to the application of 6.2 to 18 kg of nitrapyrin application $ha^{-1}$ $yr^{-1}$**

BNI Mitigation Technology

Does it work in the field?

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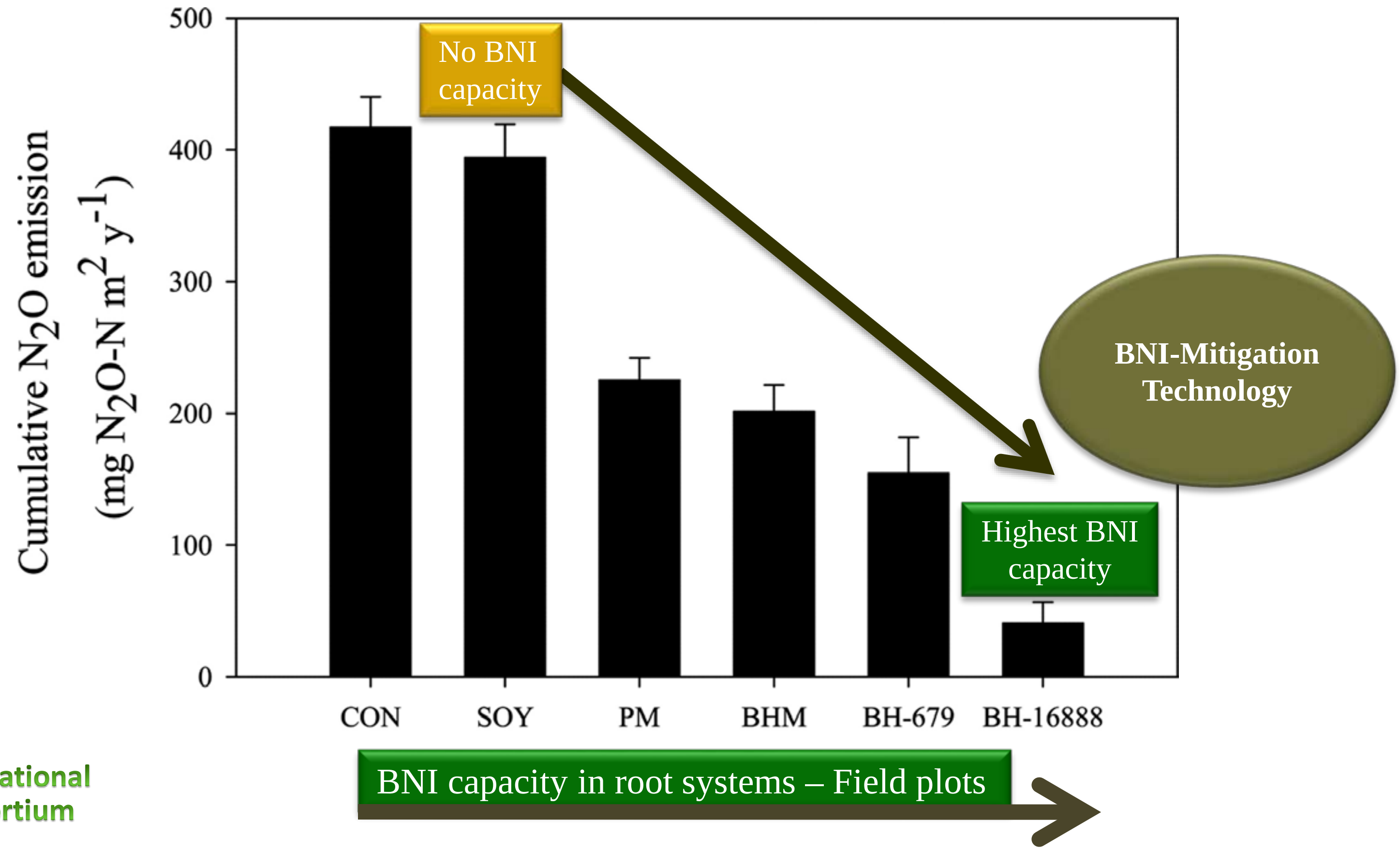
# Can we breed for high-BNI capacity in food- and -feed crops?

*Developing low-nitrifying and low-N2O emitting systems*

***Brachiaria*** **pastures suppressed $N_2O$ emissions from the field**

*Can BNI function in plants be exploited to develop low-$N_2O$ emitting systems then?*




**Cumulative $N_2O$ emissions (mg of $N_2O$ N per $m^2$ per year) from field plots of tropical pasture grasses (monitored monthly over a 3-year period, from September 2004 to November 2007)**



**Subbarao G V et al. PNAS 2009;106:17302-17307**

PNAS

# Nitrogen excreted (from urine) from grazing animals

*from managed grasslands (9 million km$^2$) is estimated at*

# >120 Tg N $y^{-1}$

*Can BNI-enabled pastures help reducing $N_2O$ emissions from these grazing systems?*

*1800 million livestock units; 182 to 392 g N excreted per animal $d^{-1}$*

**Equal to synthetic Nitrogen fertilizer to global agricultural systems**

Source: Saggar et al. 2005

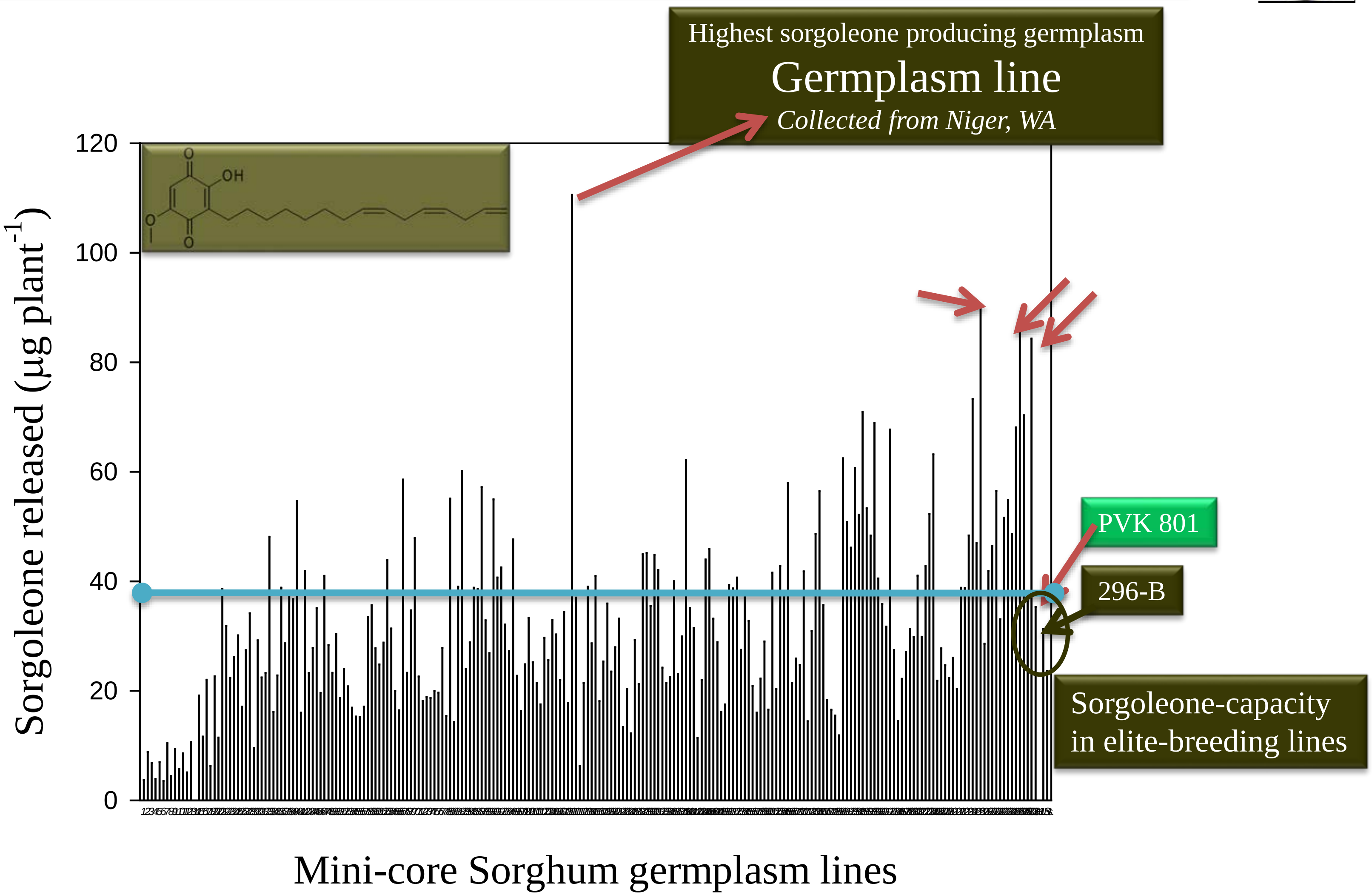
# Developing BNI-enabled crop/pasture varieties?

**Sorghum-BNI characterization at a field site in *ICRISAT, India***

**Hydrophilic BNIs released from sorghum roots**

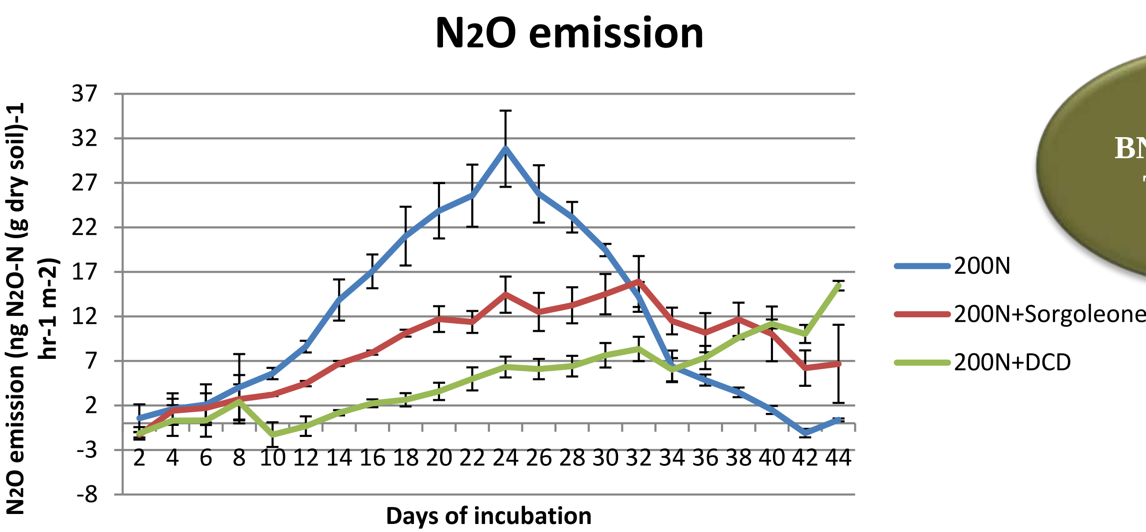

# Sorgoleone phenotyping of mini-core sorghum germplasm (231 lines) - 2015

*Breeding for high-sorgoleone producing sorghum cultivars - Feasible?*

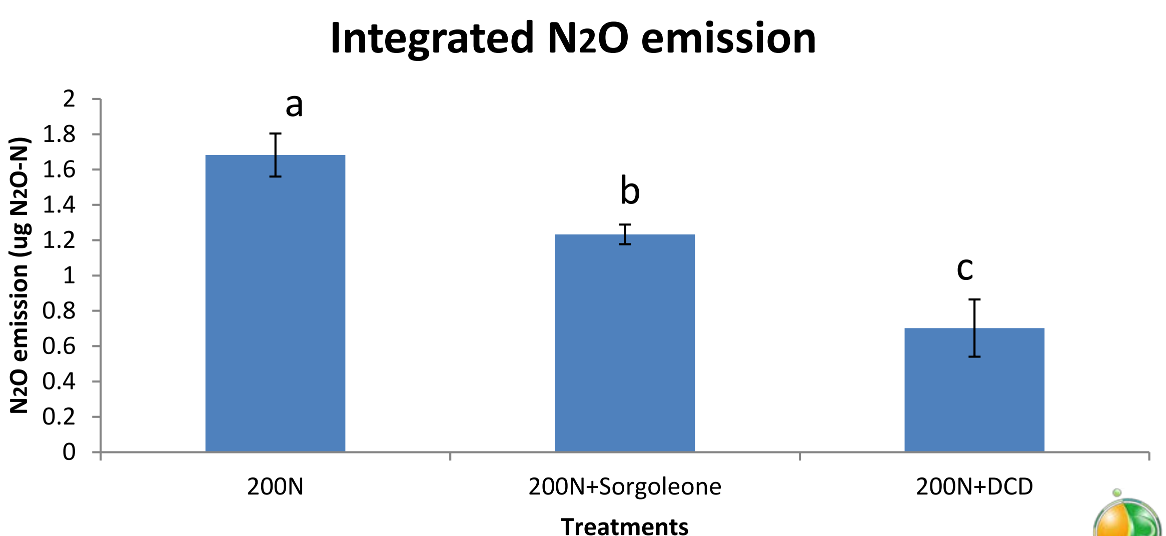


# *Sorgoleone additions to the soil suppressed $N_2O$ emissions*

*High-sorgoleone producing genetic stocks suppress $N_2O$ emissions better than low-sorgoleone producing genetic stocks?*




**BNI-Mitigation Technology**

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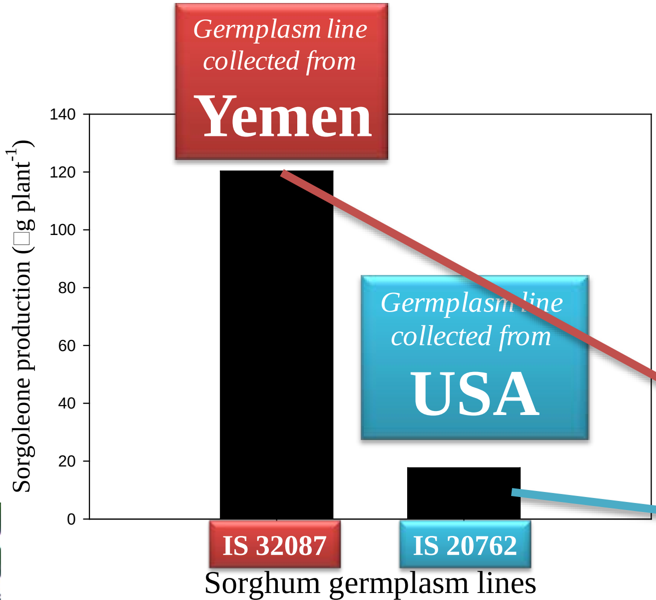
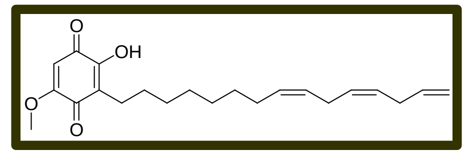
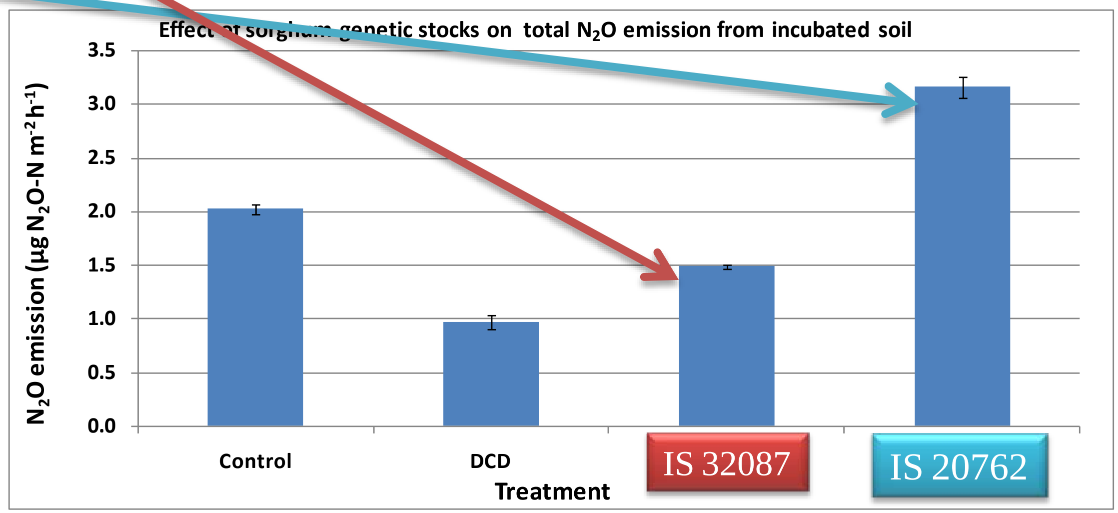
# High sorgoleone producing sorghum genetic stocks have low $N_2O$ emissions?

*Breeding for high-sorgoleone production could a proxy to develop low-$N_2O$ emitting sorghum cultivars?*



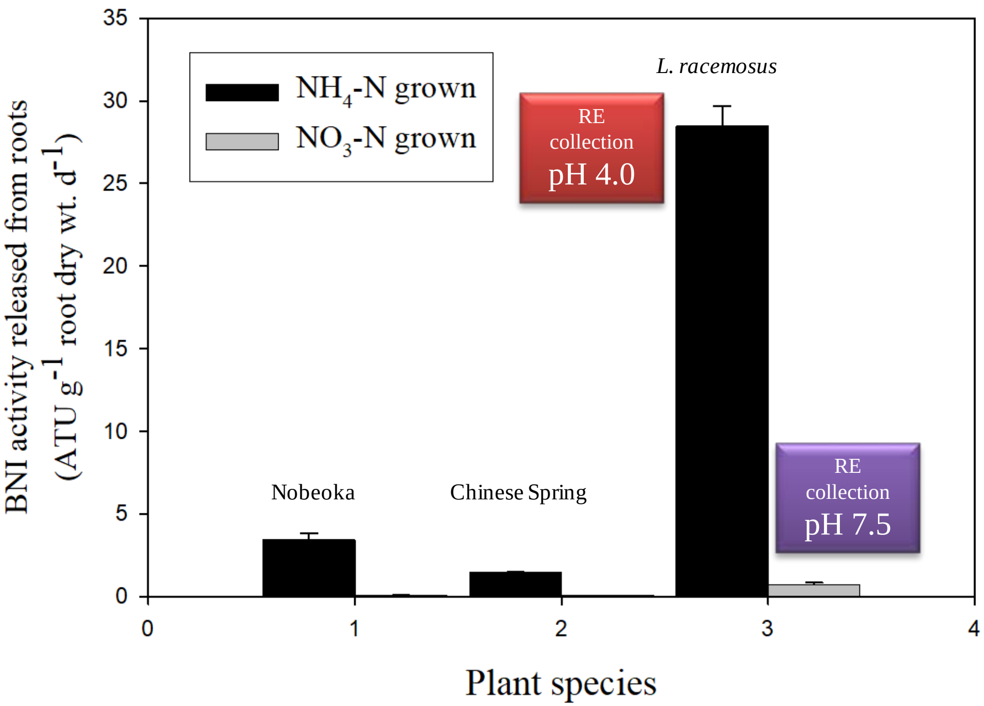




**High-sorgoleone germplasm line has 50% lower $N_2O$ emissions compared to low-sorgoleone producing germplasm**

# Wild-wheat has high-BNI capacity

**JIRCAS-CIMMYT partnership**




*Leymus* does not release BNI when grown with $NO_3^-$-N where pH of RE-collection solution will be of >6.0


*Leymus racemosus*

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# Benefits from Genetic-Mitigation using BNI-Technology

- Cost effective and Scalable
- Delivery of BNIs - precise and effective
- Cocktail of inhibitors from BNIs – more stable effect
- No negative environmental consequences
- No health issues on food or feed quality
- Improve soil-N-retention and fertility

# Portfolio of current technologies to reduce nitrification and $N_2O$ emissions

- Synthetic nitrification inhibitors
- Urease inhibitors
- Slow-release nitrogen fertilizers
- Polythene-coated nitrogen fertilizers
- Split-Nitrogen applications
- Precision farming – ‘Green-seeker’ technology
- AWD (alternate wetting and drying) for paddy rice systems

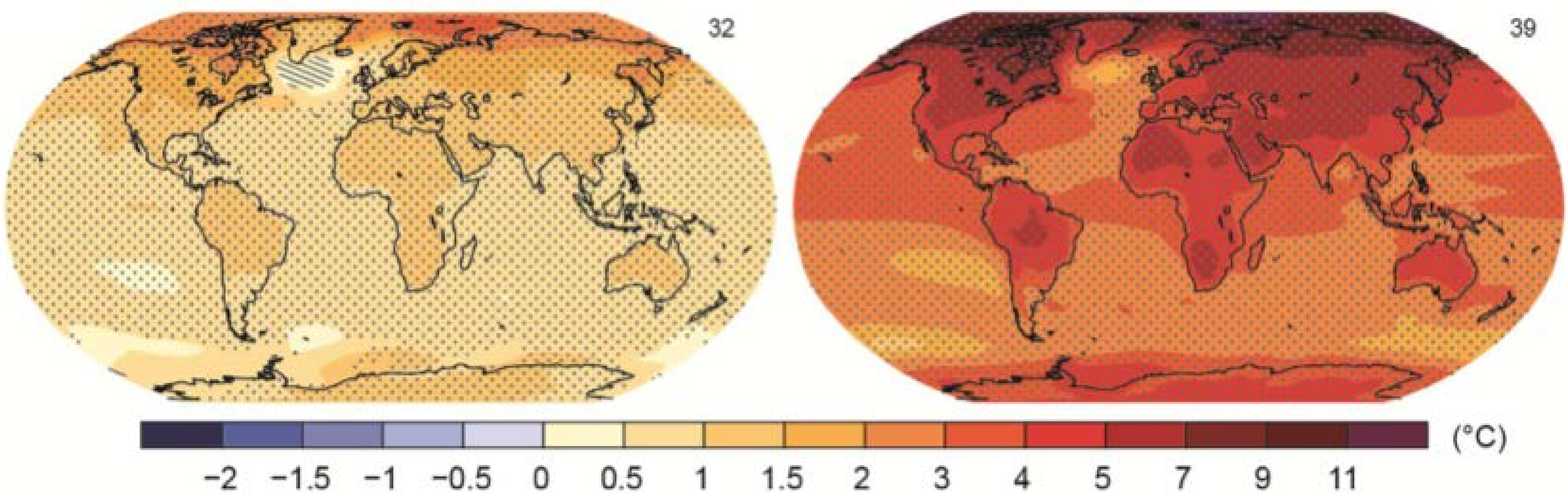
BNI-technology could become part of portfolio of technologies to address GHG emissions from agriculture

# Developing novel Mitigation-technologies
## *critical to reduce GHG emissions from agriculture*

*Paris Climate Agreement signed in 2015 calls to hold the global average temperature to <2C above preindustrial levels by for 80% reduction in GHG emissions from current levels by 2050*

**With substantial mitigation**

**Without additional**




**Change in average surface temperature (1986–2005 to 2081–2100)**

Source: IPCC AR5 synthesis report



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# Paris-Climate Agreement Signed in 2015

"... holding the increase in the global average temperature to well below 2 °C above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5 °C"

# *The smart way to address climate change is through* **Innovation**

## *Energy Production and Transport Sectors*

*Solar-electricity, Hybrid Cars, Electric cars are some of the GHG reducing technologies emerged recently*

*Reducing GHG emissions from Agriculture reduces N-pollution, N-fertilizer consumption, improve soil fertility and sustainability of production systems*

*Low $N_2O$ emission systems are a 'WIN WIN' situation for both environment and for Agriculture*

*Funding support for BNI Research*

MAFF
MOFA – CGIAR Collaborators
CRP-WHEAT
JIRCAS-President's special grants
JSPS Research Grants

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# Arctic is melting fast

## Time for action

*from Agricultural Scientific Community*

Huge waterfall spouting from the ice edge of Brasvell Glacier – Getty image

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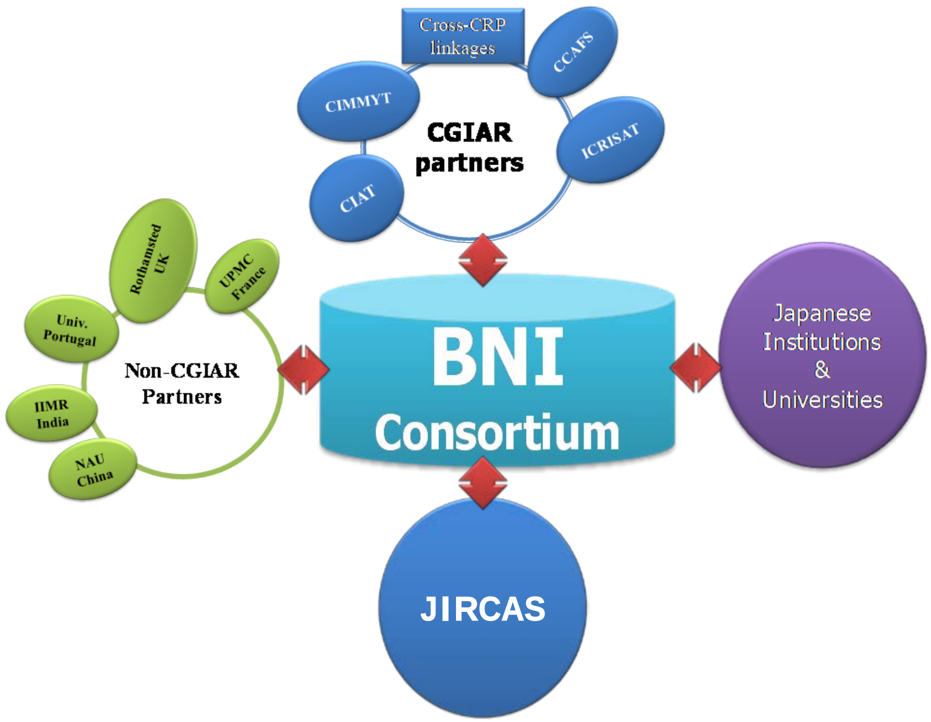


**Thank You for the attention**