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Sustainable intensification of grain legumes with smallholders in Africa through nitrogen fixation: highlights from the N2Africa project

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Improving Nitrogen Fixation in grain legumes is central to the sustainable intensification of agriculture in sub-Saharan Africa (SSA) and inoculation with effective rhizobia can make an important contribution to this goal. Genetic and phenotypic studies have identified large taxonomic diversity and differences in symbiotic effectiveness between isolates from SSA soils, suggesting that there is potential for developing more effective inoculants from native bacteria. The N2Africa project has pursued two approaches in this regard: First, identification of elite strains from native rhizobial collections with the aim of developing inoculants for local production in SSA and second, promotion of inoculation with effective bacterial strains at scale. Here, we report the genetic and symbiotic diversity of indigenous isolates, success with the search for elite strains and achievements of the project in getting the inoculant technology out to farmers at a larger scale through Private Public Partnership (PPP). Response of crops to inoculation across a large number of smallholder's farms, covering diverse soil fertility and agro-ecological conditions, was evident. Commonly, increased grain yield of >10% over yield on control plots (a yield level assumed to be visible to farmers) was realized for most farmers. However, observed grain yields on control plots and responses to inoculation on individual farms varied greatly with a relative yield responses ranging from 3% - 100%. The additive benefits and possibilities for a wide scale promotion of inoculant technology to smallholders through a PPP approach will be discussed.

How to refer your abstract:
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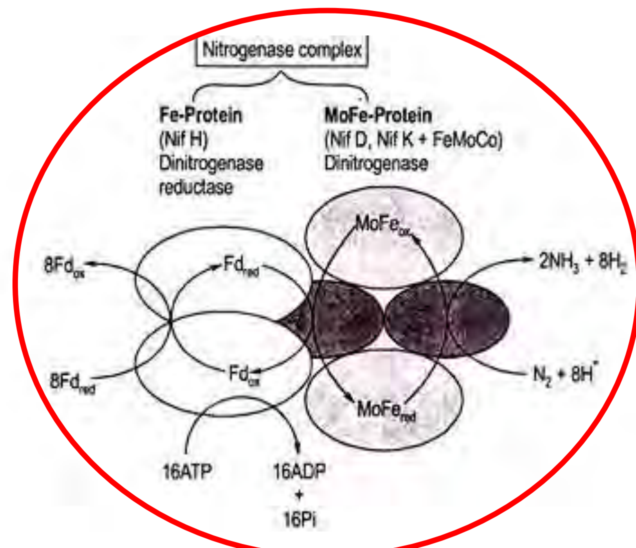
N2Africa - www.N2Africa.org

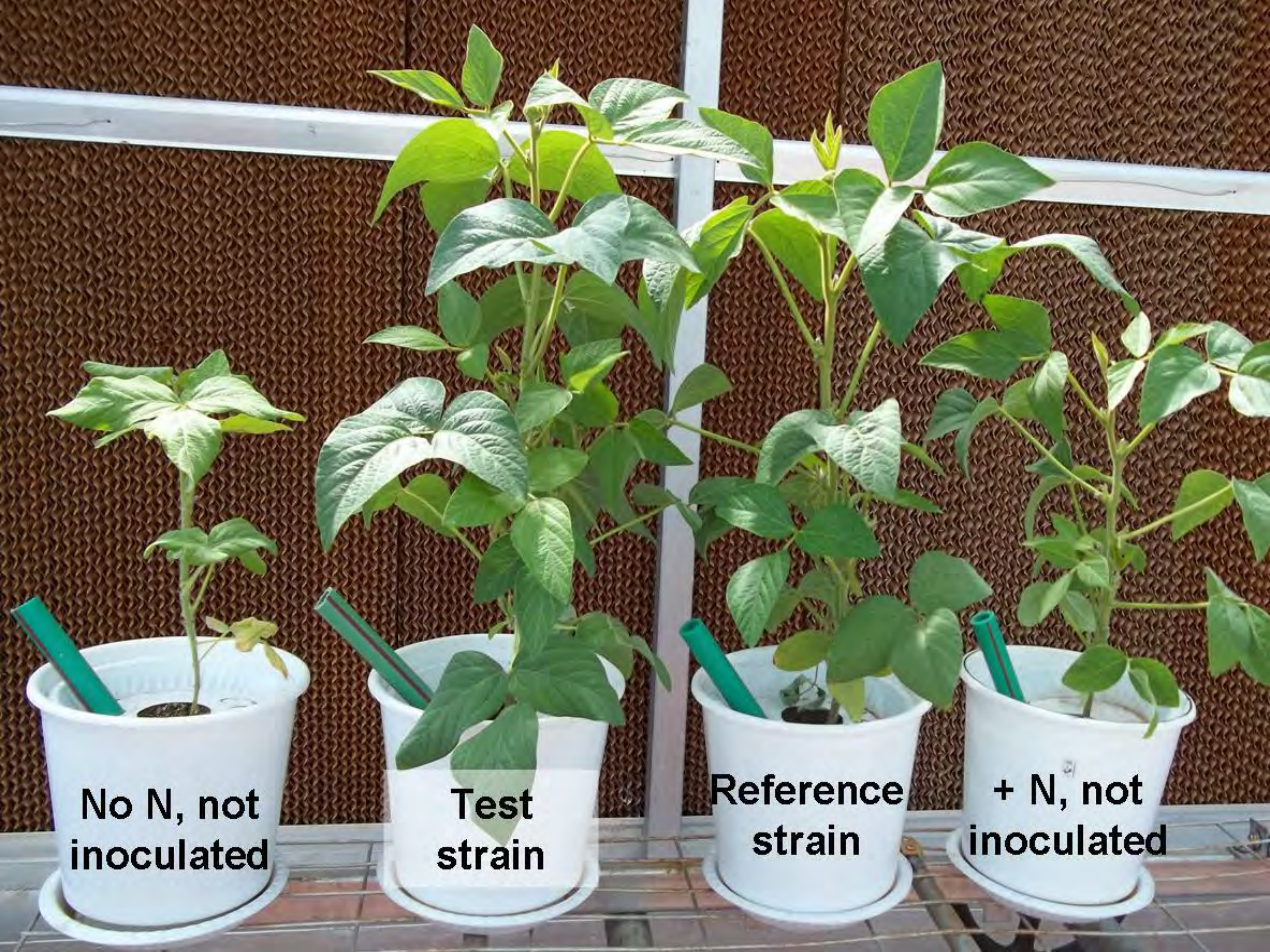
Sustainable Intensification of Grain Legumes with Smallholders in Africa through Nitrogen Fixation:
Highlights from the N2Africa project

by Endalkachew Wolde-meskel, country coordinator N2Africa project, ILRI-Addis, Ethiopia



$$N{\equiv}N \Rightarrow NH_4^+$$

Putting nitrogen fixation to work for smallholder farmers in Africa


No N, not inoculated
Test strain
Reference strain
+ N, not inoculated

- The project
- Biodiversity of rhizobia (genetic and symbiotic diversity): *the case of Ethiopia*
- BNF technology benefiting smallholder in Africa
- PPP for scaling out of the technology


+R+ DAP, Nasir
+R+ DAP, Ibado
-R- DAP, Nasir
-R- DAP , Ibado


Mr. Mulatu, Ethiopia:
Even under the current drought, the inoculated CB podded better

Smallholders demand for access to input, & **market link**

The underlying problem - poor soil fertility

Heterogeneity - what some authors - Scoones/Toulmin/Leach/Fairhead have described as ‘making new soils’ ‘carving new niches out of barren land’ - attractive ideas - man in synergy with nature

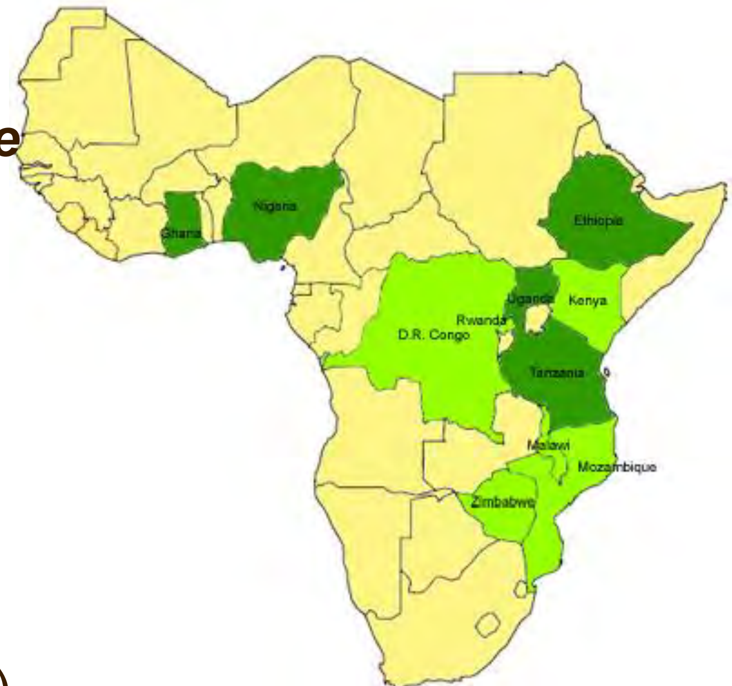
Potential solutions - Nitrogen fixing legumes

“But what can we use these crops for?
N.B. Soil fertility improvement is a secondary goal – farmers have consistently rejected green manures, cover crops and fertilizer trees

N2Africa - www.N2Africa.org

- Led by Wageningen University; with IITA, ILRI, AGRA and **many national partners**

- Implemented in 11 countries – Ghana, Nigeria, Ethiopia, Tanzania, Uganda (***Core countries***) and DRC, Kenya, Malawi, Mozambique, Rwanda, Zimbabwe (***Tier 1 countries***)



- 1st Phase 2009-2013 – **Proof of concept** (US$22M)
- 2nd Phase 2014-2018 – **Scaling through** partnerships; institutionalisation (US$30M)

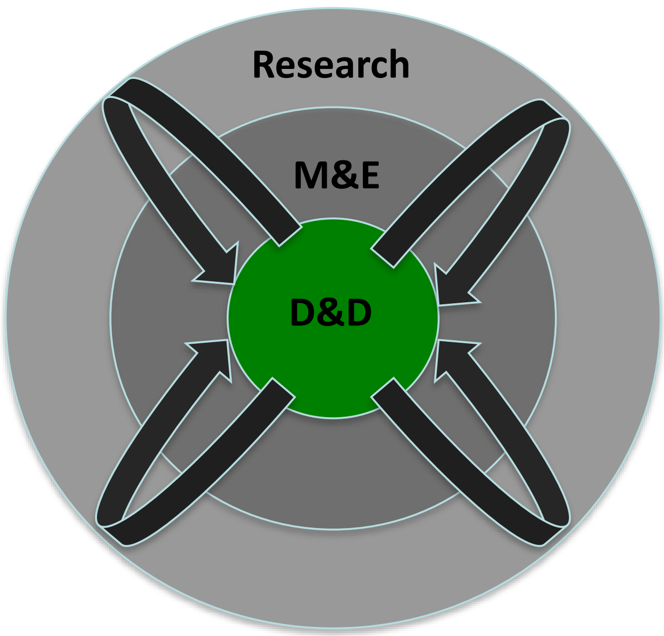
N2Africa – target legumes

Countries	Target Legume Crops
West Africa	Cowpea, Groundnut, Soybean
East and Central	Cowpea, Groundnut, Soybean, Common Bean Chickpea & Faba bean (in Eth.)
Southern Africa	Cowpea, Groundnut, Soybean, Common Bean

How to increase the inputs from N_2-fixation

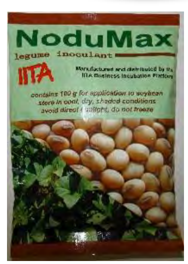
- Increase the area of land cropped with legumes (targeting of technologies)
- Increase legume productivity – agronomy and P fertilizer
- Select better legume varieties
- Select better rhizobial strains and inoculate
- Link to markets and create new enterprises to increase demand for legumes

N2Africa is a development to research project



- Delivery and dissemination are the core
- Monitoring & evaluation provides the learning
- Research analyses and feeds back

Registered inocu. in TZ



Registered, inoc., Nigeria

Registered, inoc., in Eth.

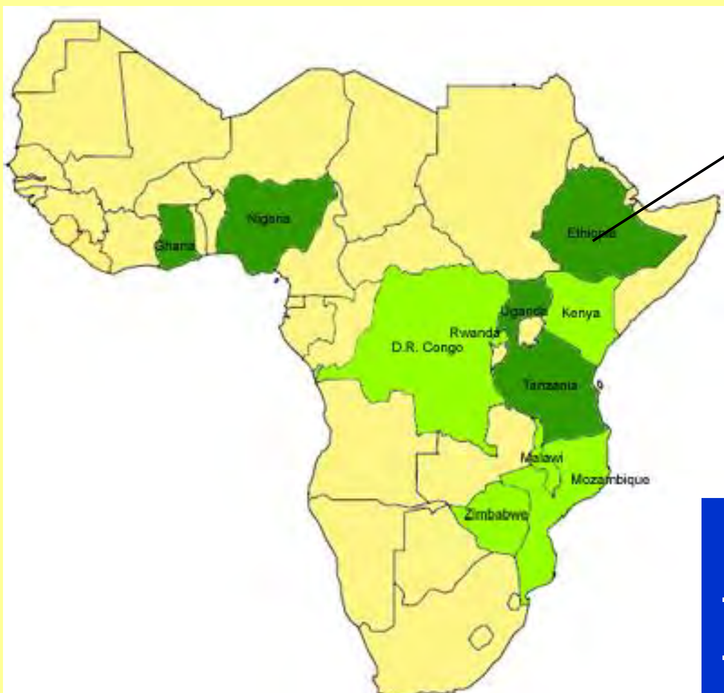
Genotype × Environment × Management

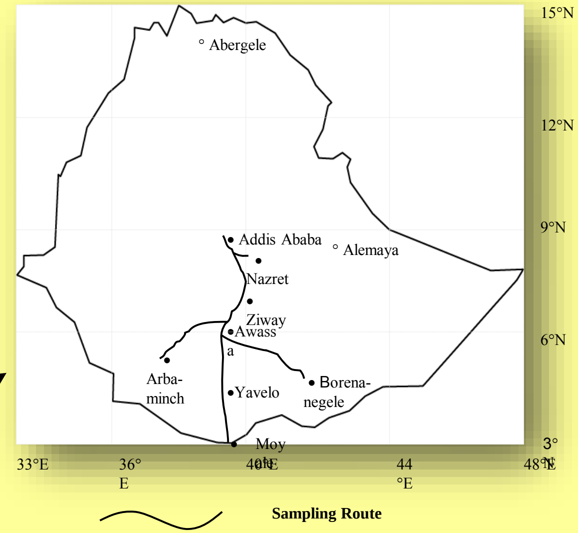
$$(G_L \times G_R) \times E \times M$$

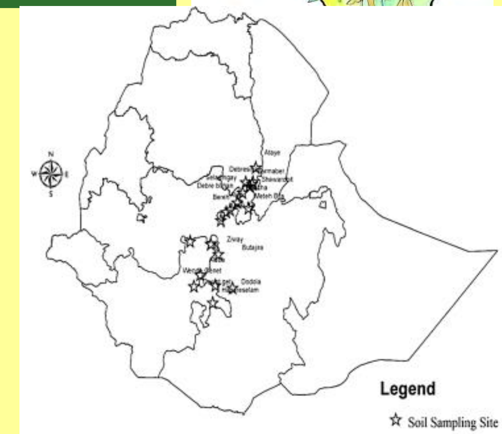
Where:
G_L = legume genotype
G_R = rhizobial strain
E = environment
- climate (temperature x rainfall x daylength etc) - to encompass length of growing season etc
- soils (nutrient limitations, acidity and toxicities)

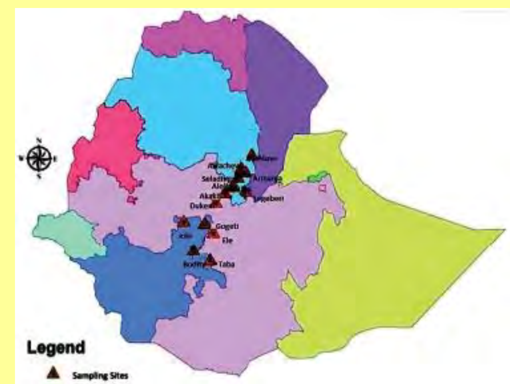
M = management
- agronomy – inoculation, seeding rates, plant density (row spacing etc), weeding,
- (Diseases and pests are also a function of *G* x *E* x *M*....)

Collection: covering diverse agro-ecological locations (Alt., T^o, RF, pH..)



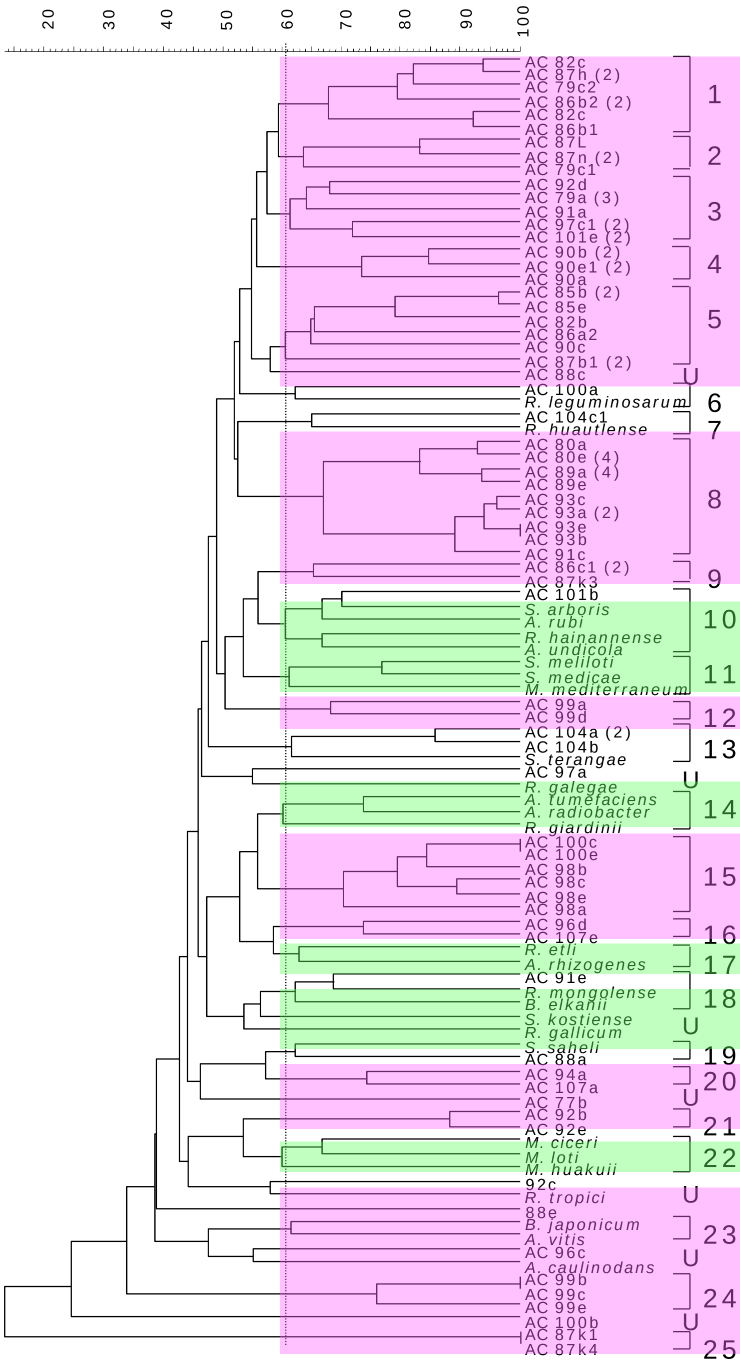






Increasing size of bio-bank
- Ethiopia
- Kenya
- Ghana
- Nigeria
- Zimbabwe

<u>Genomic diversity</u> of Ethiopian rhizobia (AFLP dendrogram)

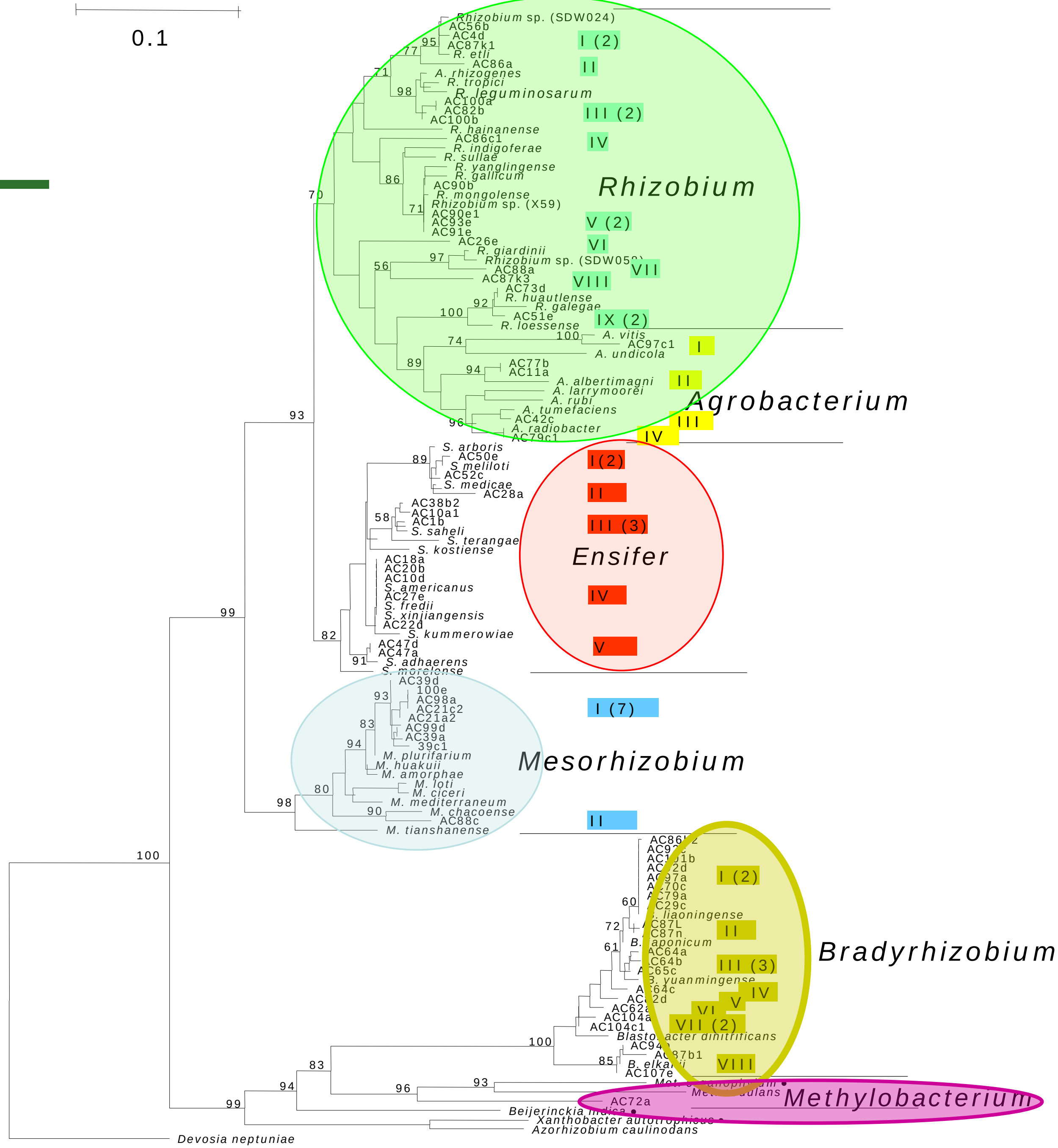


• **25 clusters (test strains found in 19)**

• **11 unclusterd positions (7 are test strains)**

- **Not linked to references (83%)**
- **References form separate clusters or unclustered**

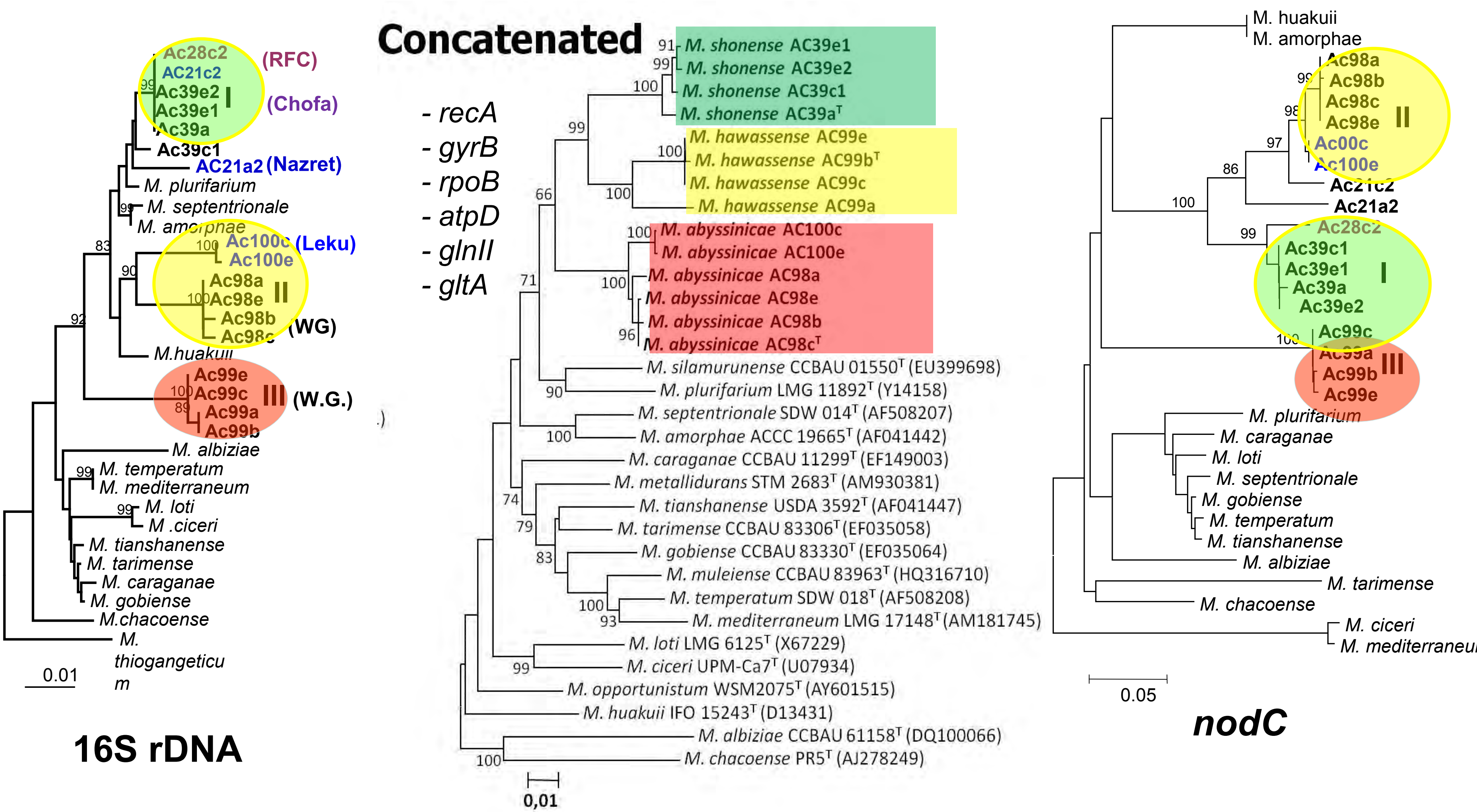
- Ethiopian soils harbour genomically diverse rhizobia not related to reference species
- These may represent taxonomic groups as yet unrecognised and warrant further phylogenetic analysis



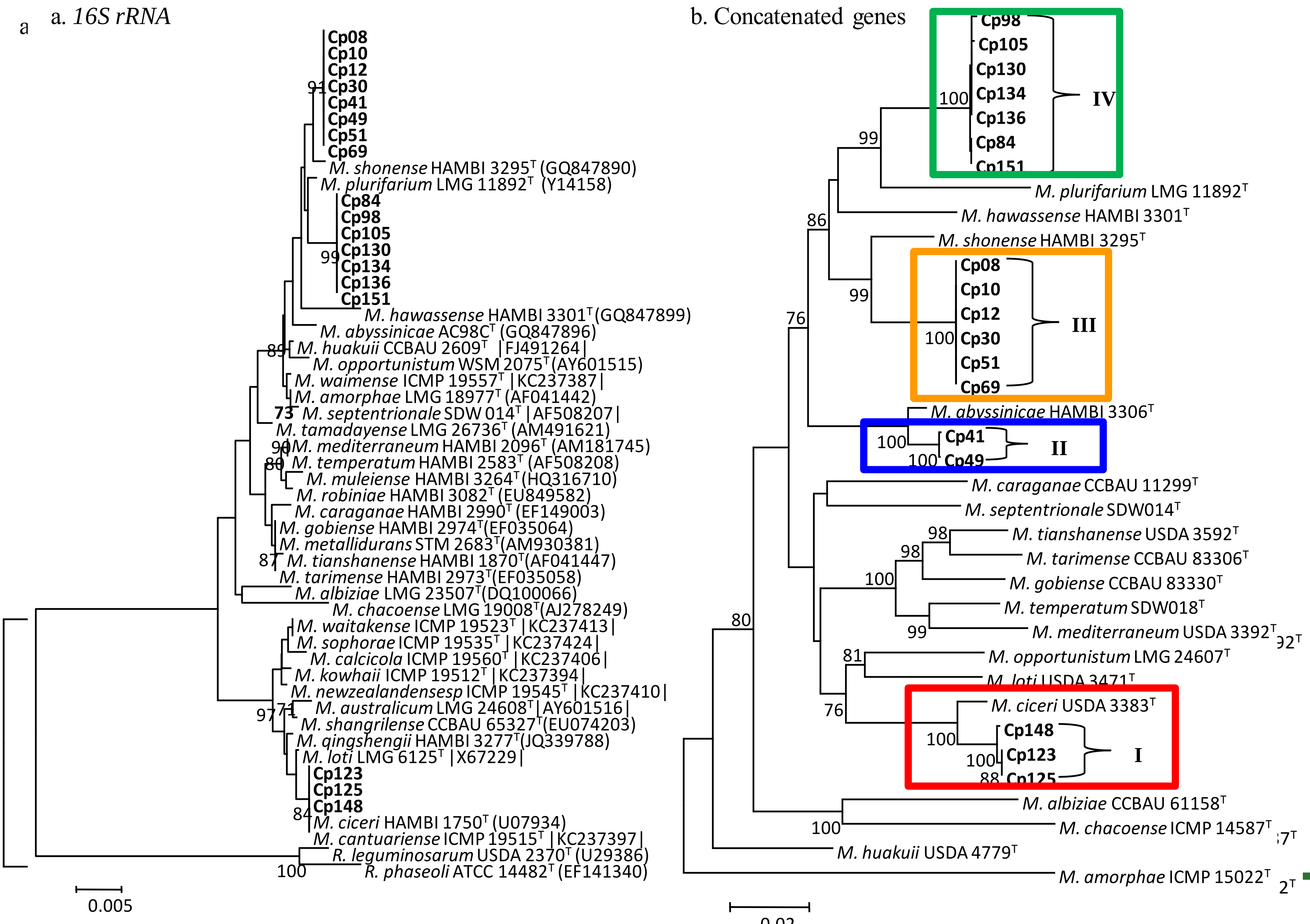
Neighbour-joining Phylogeny estimated from partial 16S rRNA (67 test strains)

New *Mesorhizonium* sp. *M. hawassense, shonense, abyssinica*

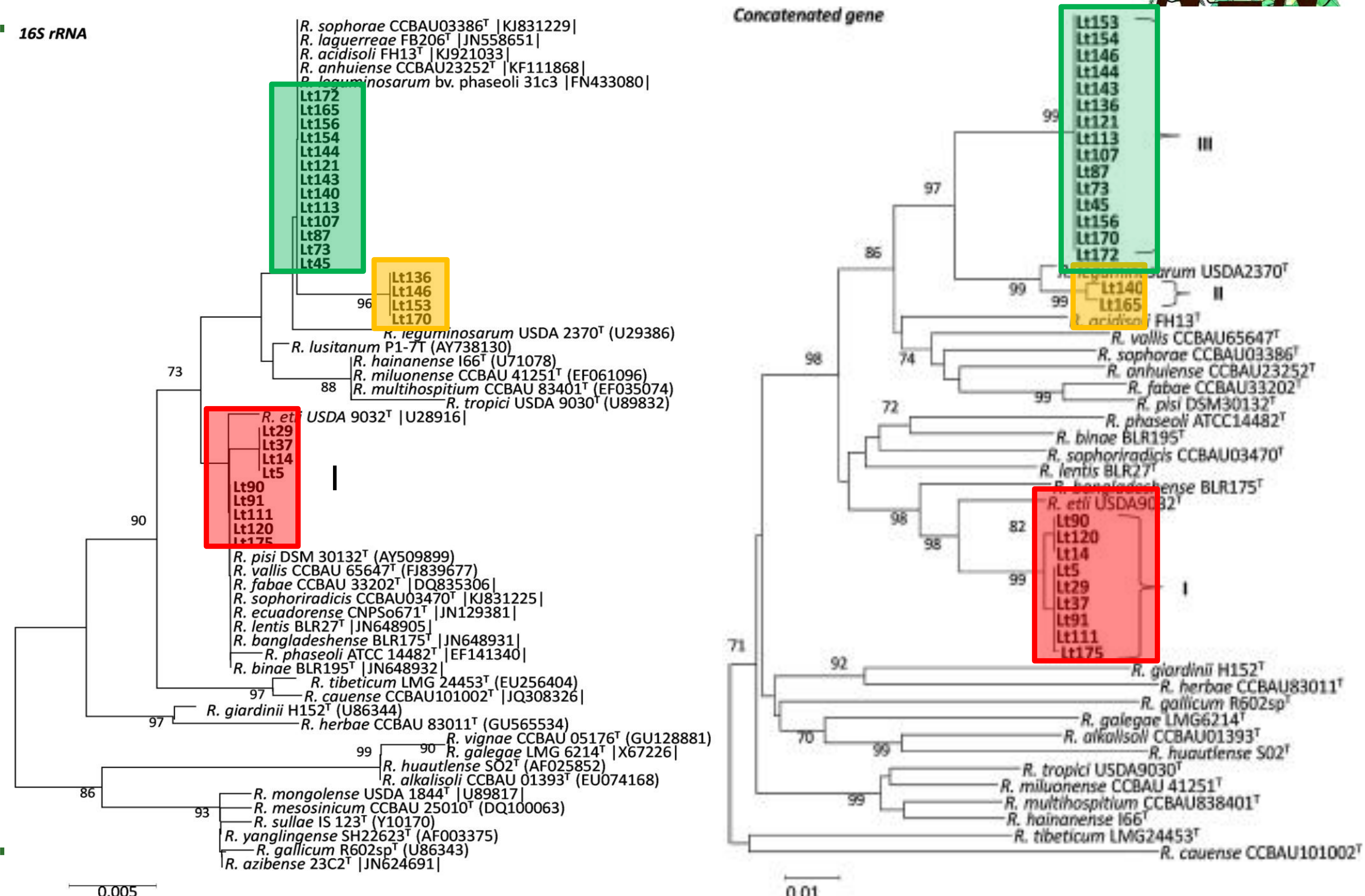
IJSEM (2013), 63, 1746–1753



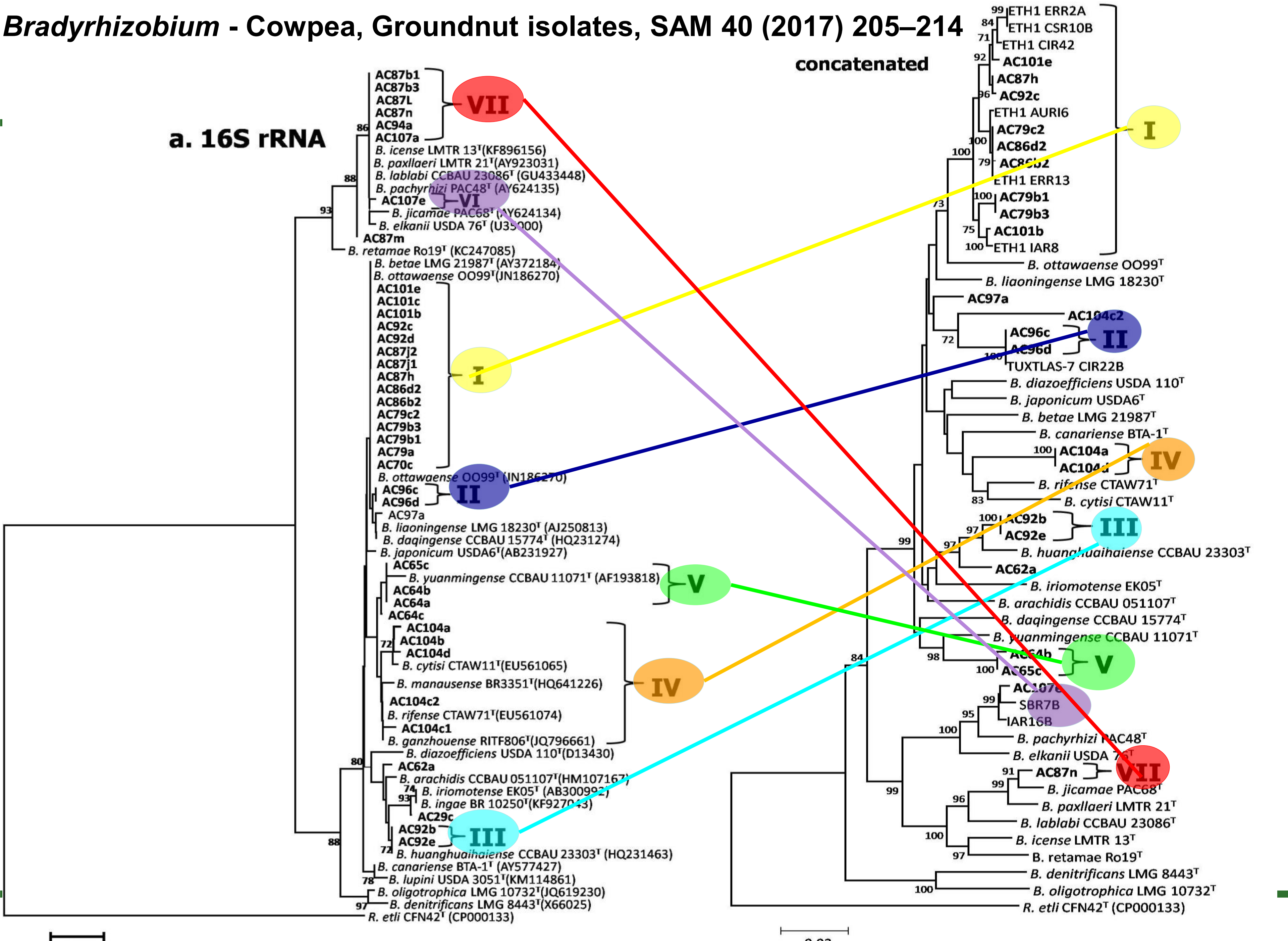
Mesorhizobium- Chickpea Strains (Can J Microbiol. 2017 63(8):690-707)



Rhizobium - (lentil isolates), SAM 40 (2017) 22–33



Bradyrhizobium - Cowpea, Groundnut isolates, SAM 40 (2017) 205–214



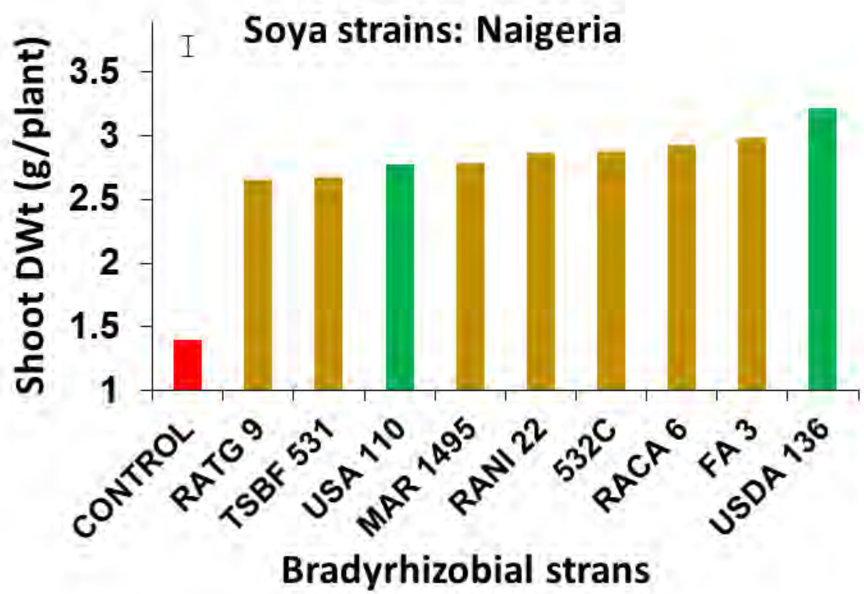
II. Diversity in Symbiotic Performances

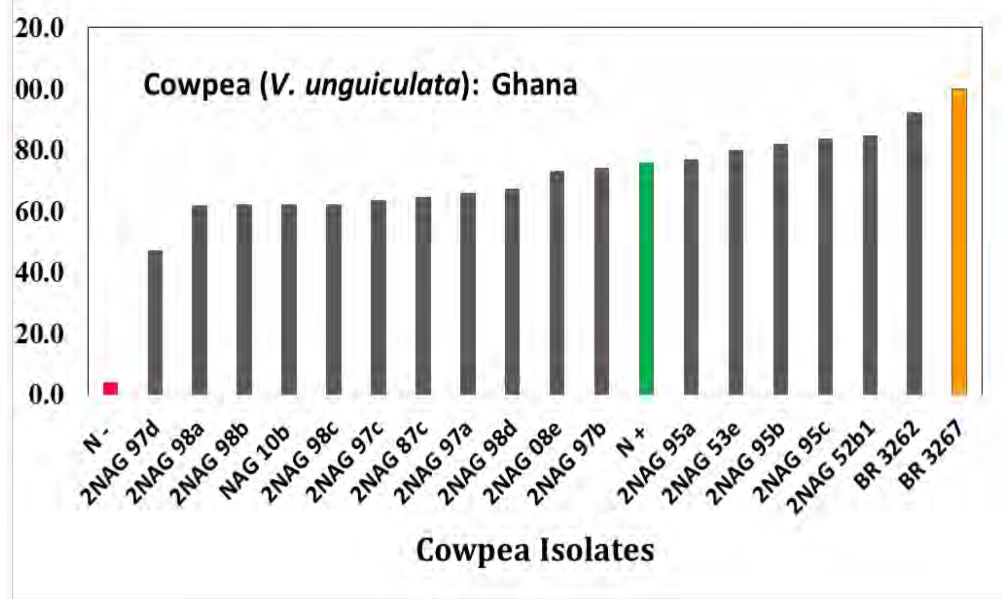
Screening rhizobia for symbiotic effectiveness and PGP effect, **(which strain?)**

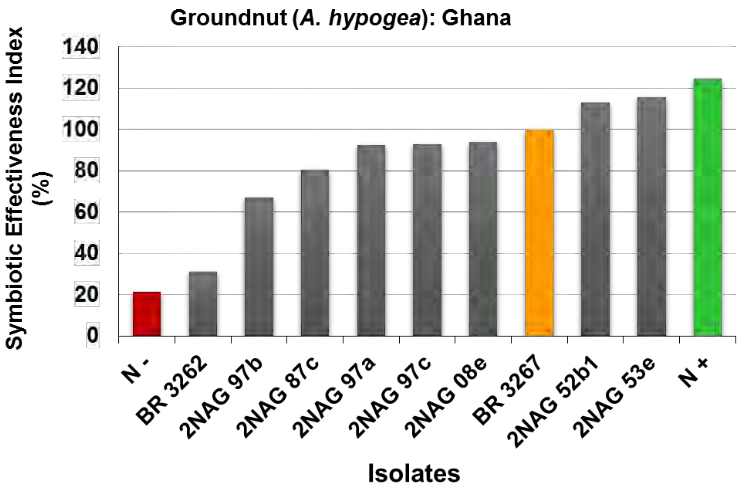
Symbiotic effectiveness

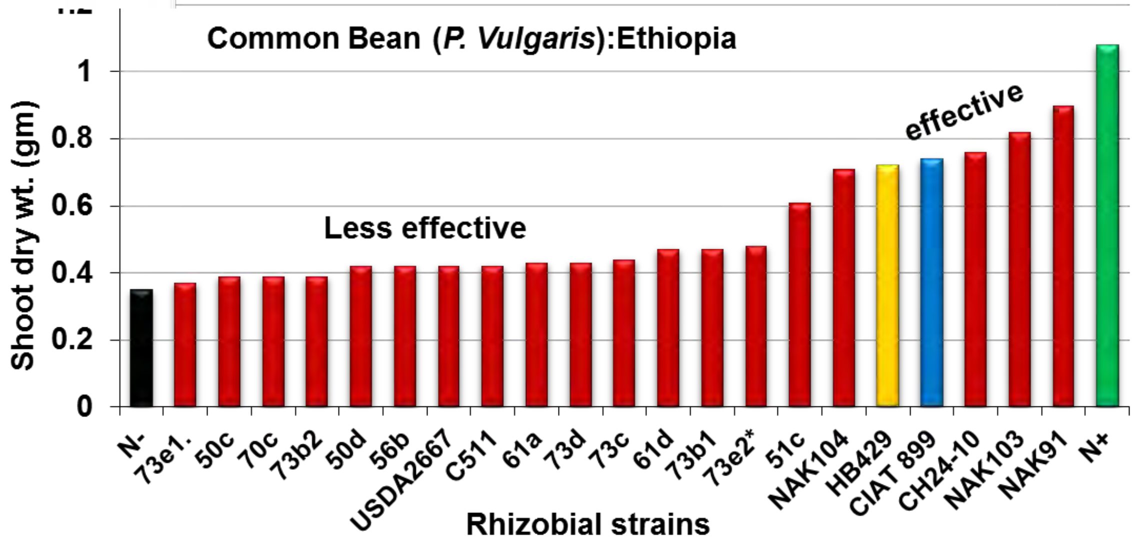
- **In glasshouses**
- **Under field condition**
- **V by S by L, Multi-location**

Symbiotic effectiveness (glasshouses)



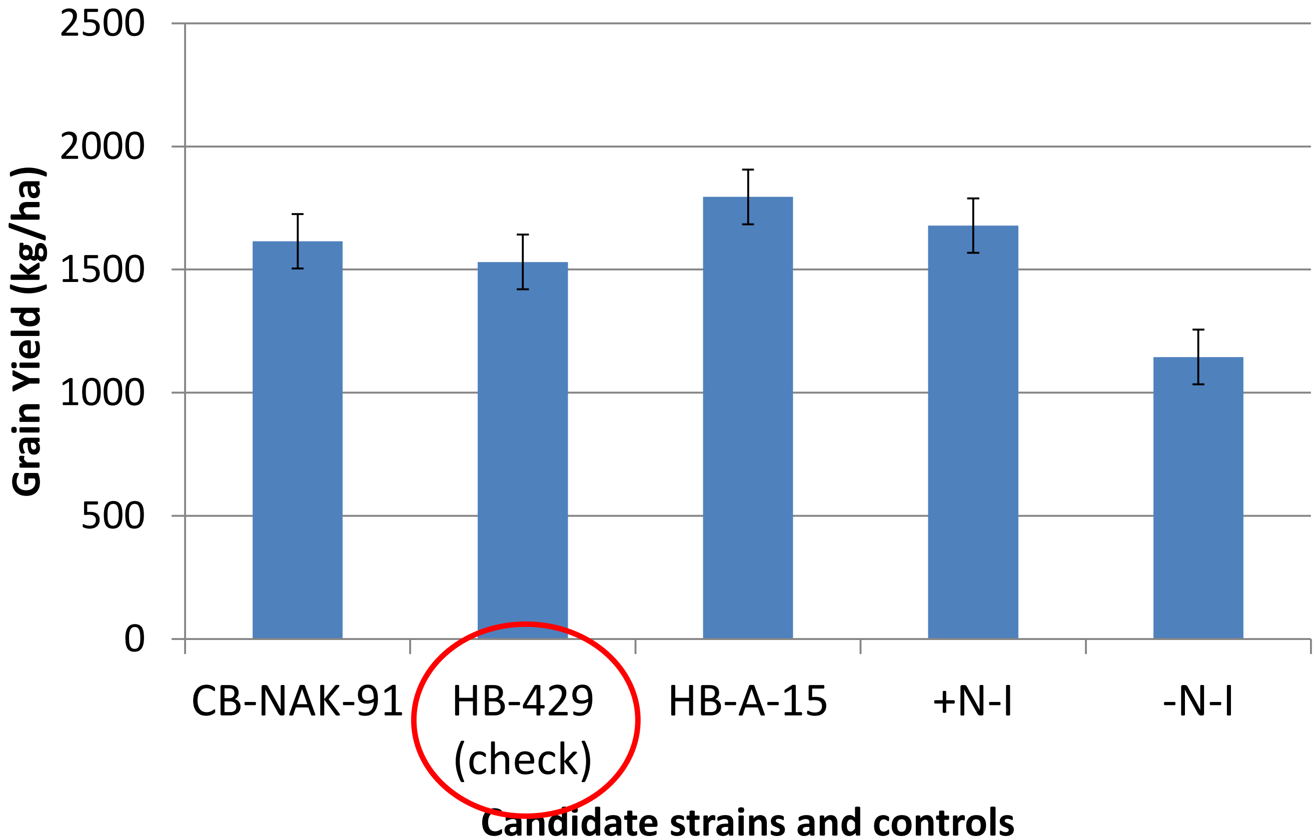






A search for more effective strains (S x V x L)

Overall performances of candidate elite strains, *P. vulgaris* (GY is an average of the three varieties at different Location)

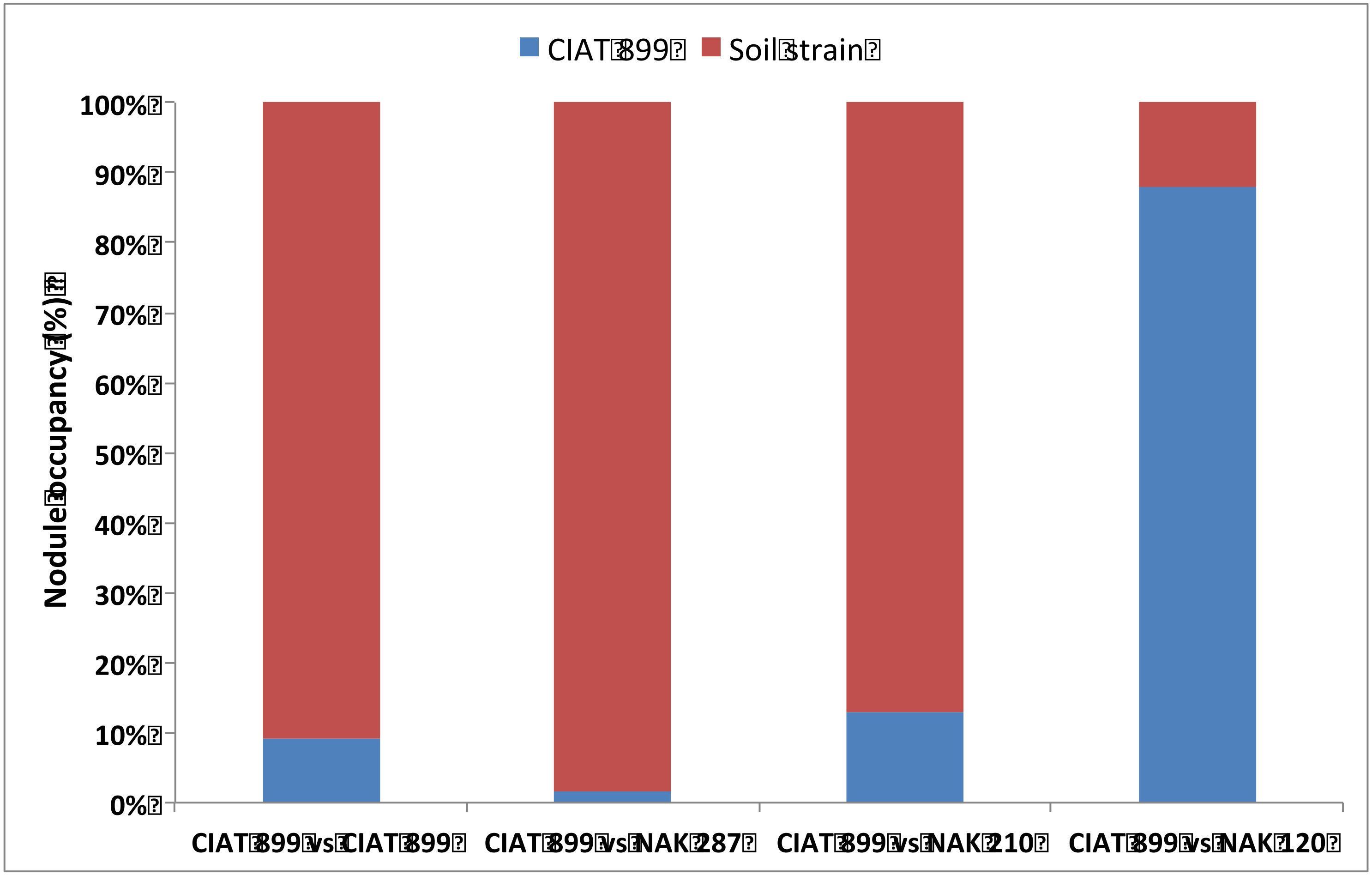


Competition against established rhizobia in soil

Strains isolated from beans in Kenya were marked with a plasmid-borne *celB* gene and co-inoculated with CIAT 899 marked with *gusA* (blue)

George Mwenda, Murdoch University

Competition with rhizobia established in soil



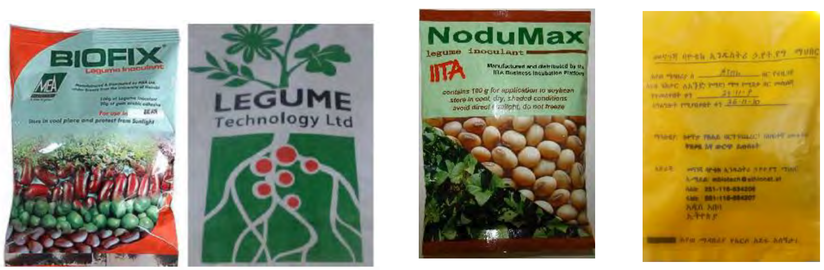
Nodule occupancies following sowing of inoculated bean (10^6 cells of CIAT 899 per seed) into soils with 10^5 cells per g of soil of CIAT 899, NAK 287, NAK 210 or NAK 120

Mwenda, Terpolilli, Howieson and O'Hara Murdoch University, WA

Targeting of technology

Which strain? What works where? Why? for whom?

Crop targeted inoculants identified & ready

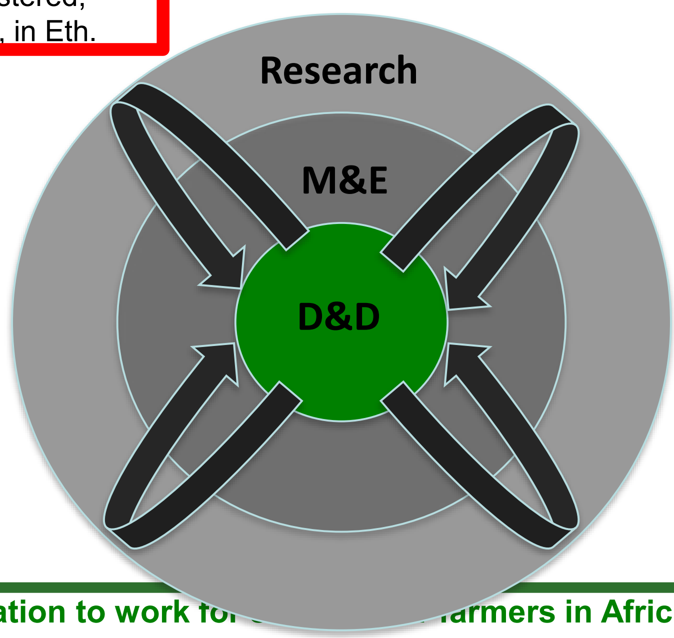


Registered inocu. in TZ

Registered, inoc., Nigeria

Registered, inoc., in Eth.

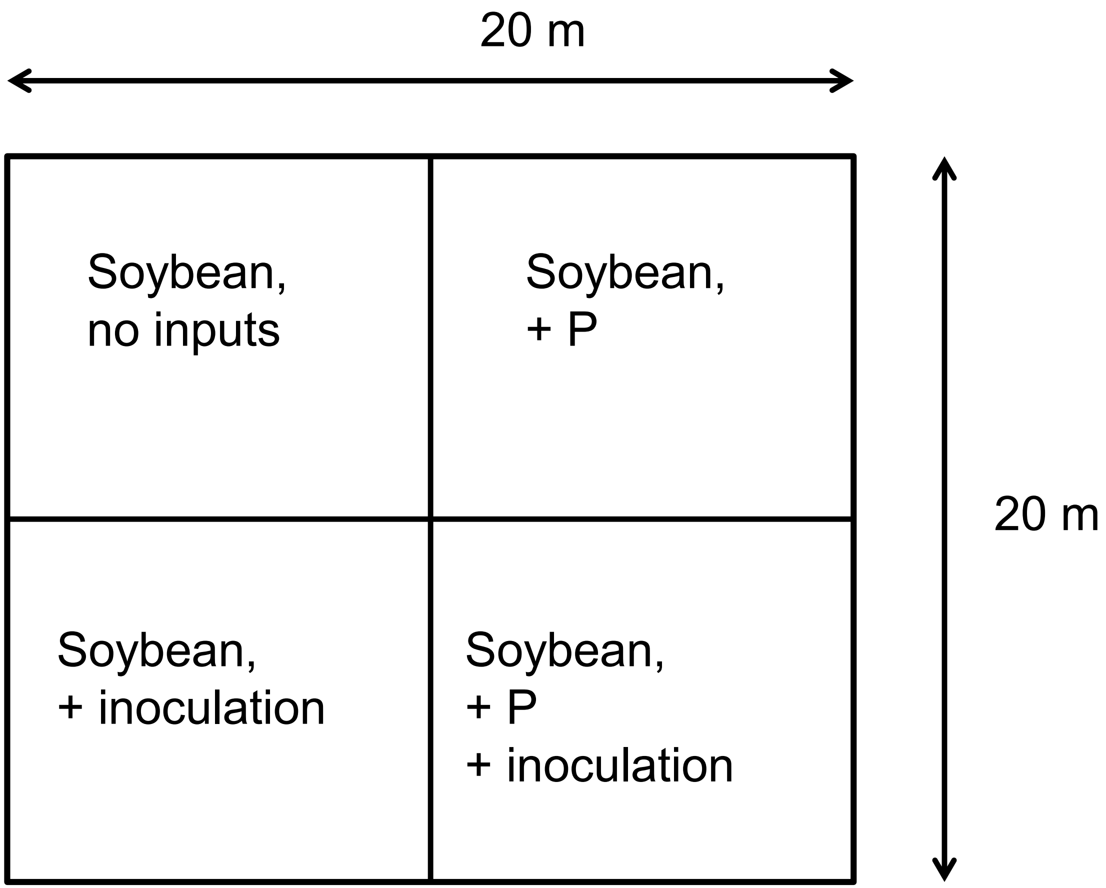
Improved varieties available



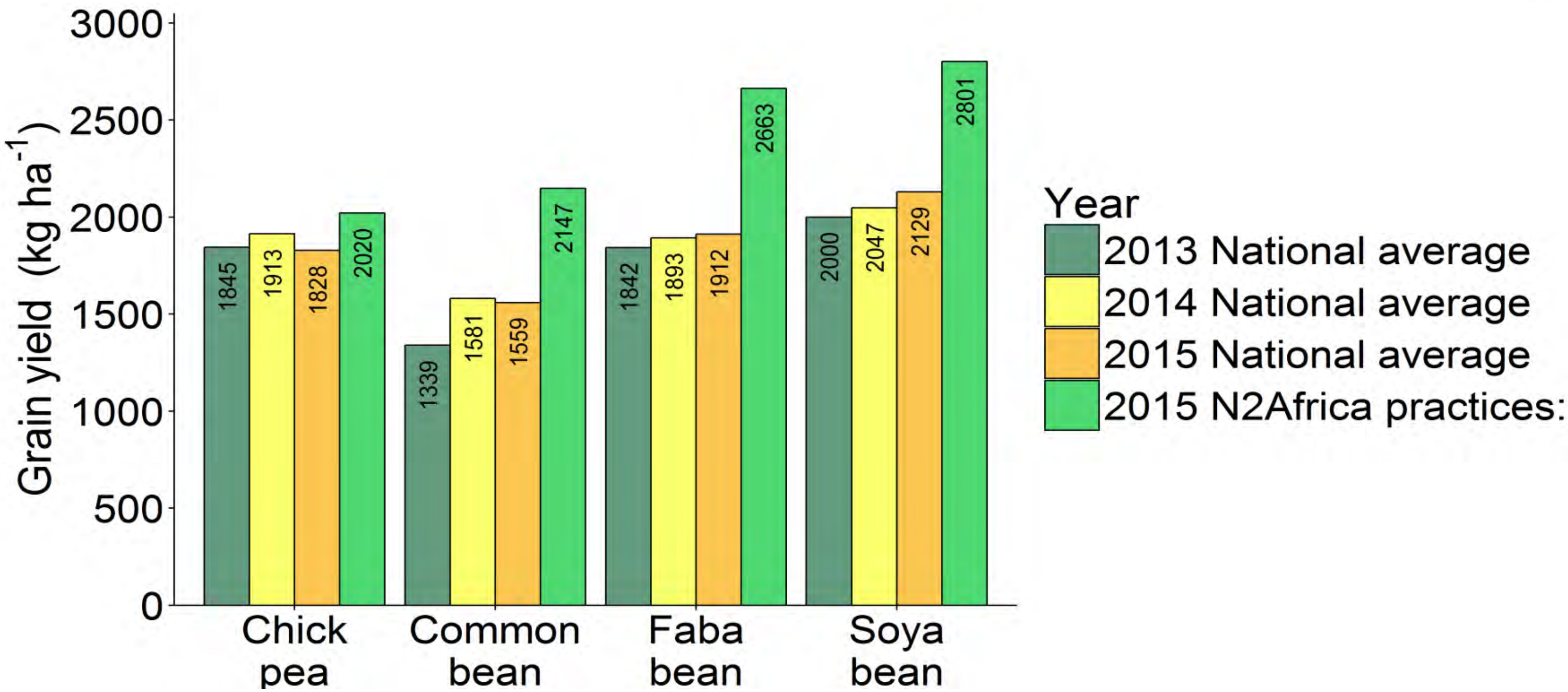
Targeting

Country
↕
Region
↕
Farming System
↕
Farm (household)
↕
Field

A ‘demonstration’ trial or farmer try-out



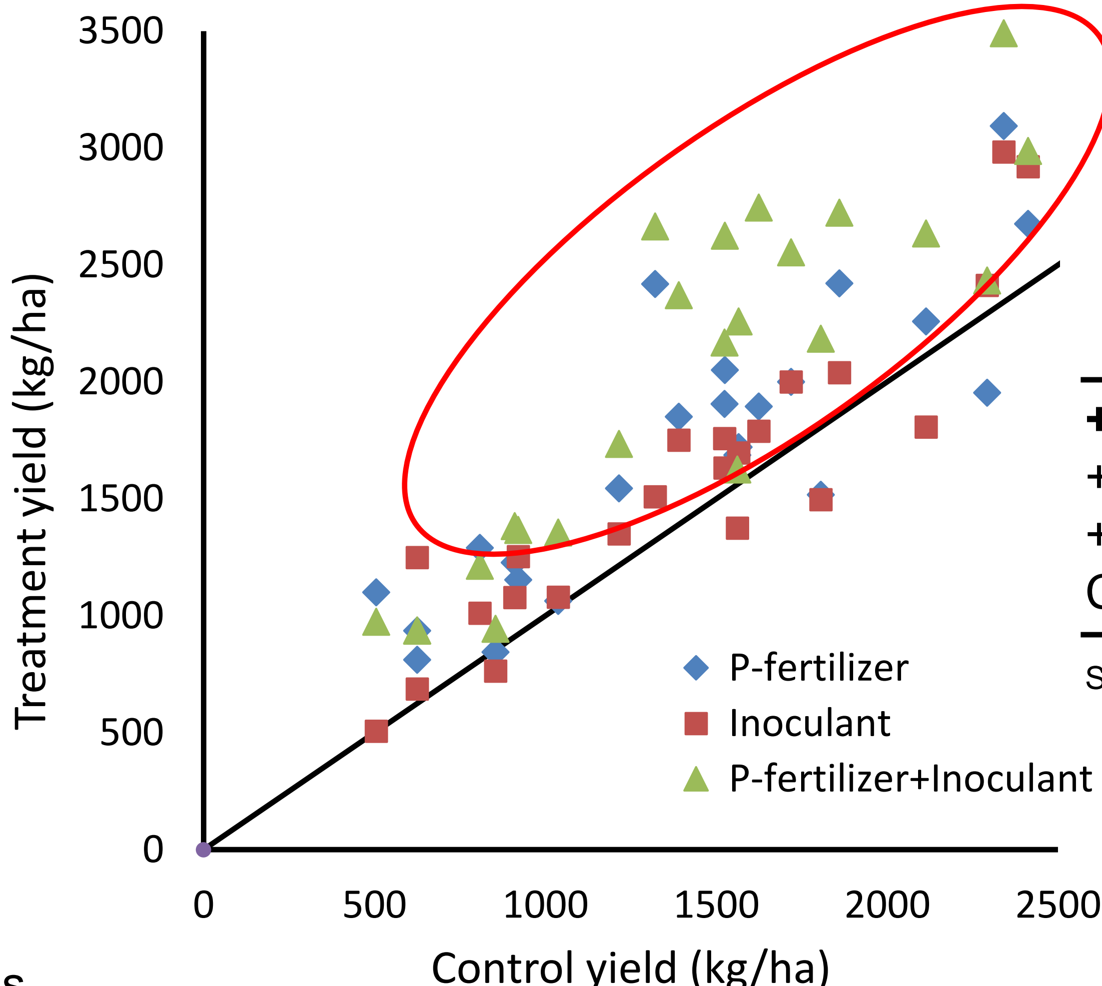
I +P Increased average grain yield of N2Africa target legumes



Mean legume yields obtained on N2Africa's demonstration trials compared to national average legume yields of three years (Ethiopian Central Statistical Agency 2014-2016 reports).

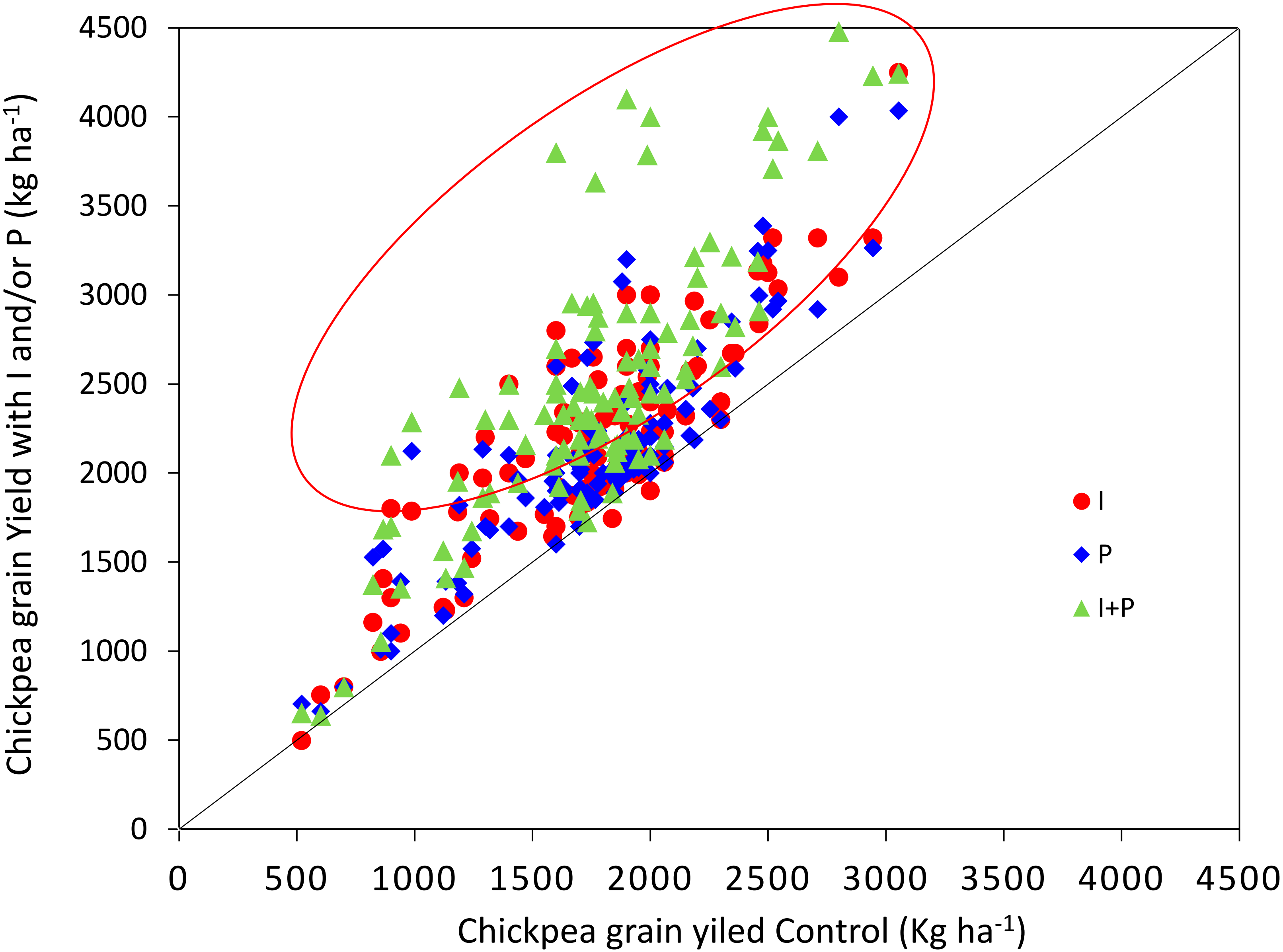
Effect of Inoculation and/or Inoculant on common bean, Ethiopia, 2015

23 on-farm trials

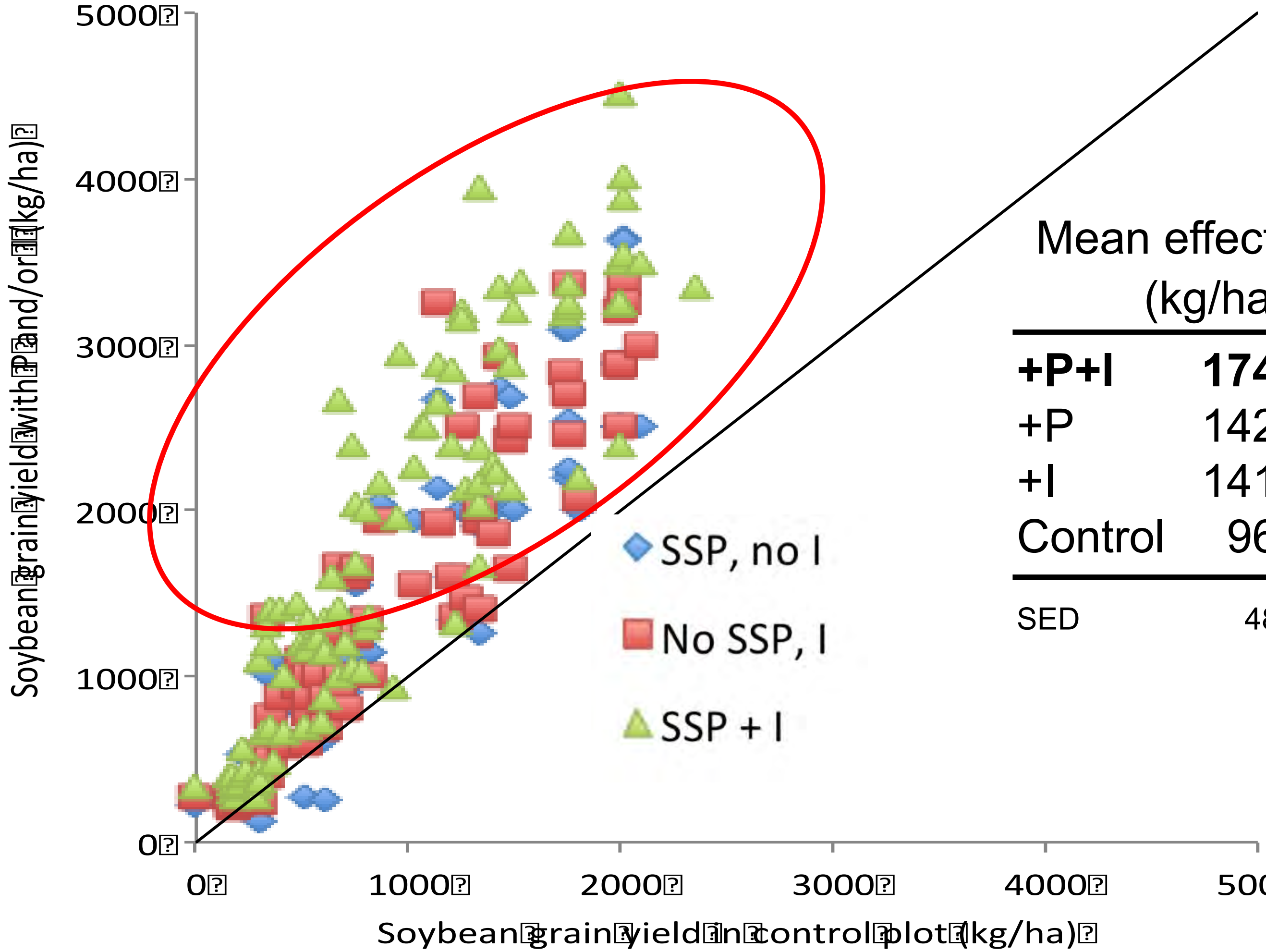


Mean effects (kg/ha)	
+P+I	**2013**
+P	1714
+I	1572
Control	1415
SED	63.6

On farm grain yield of chickpea with Inoculation and/or P-fertilizer in Ethiopia, 2014 - 2016



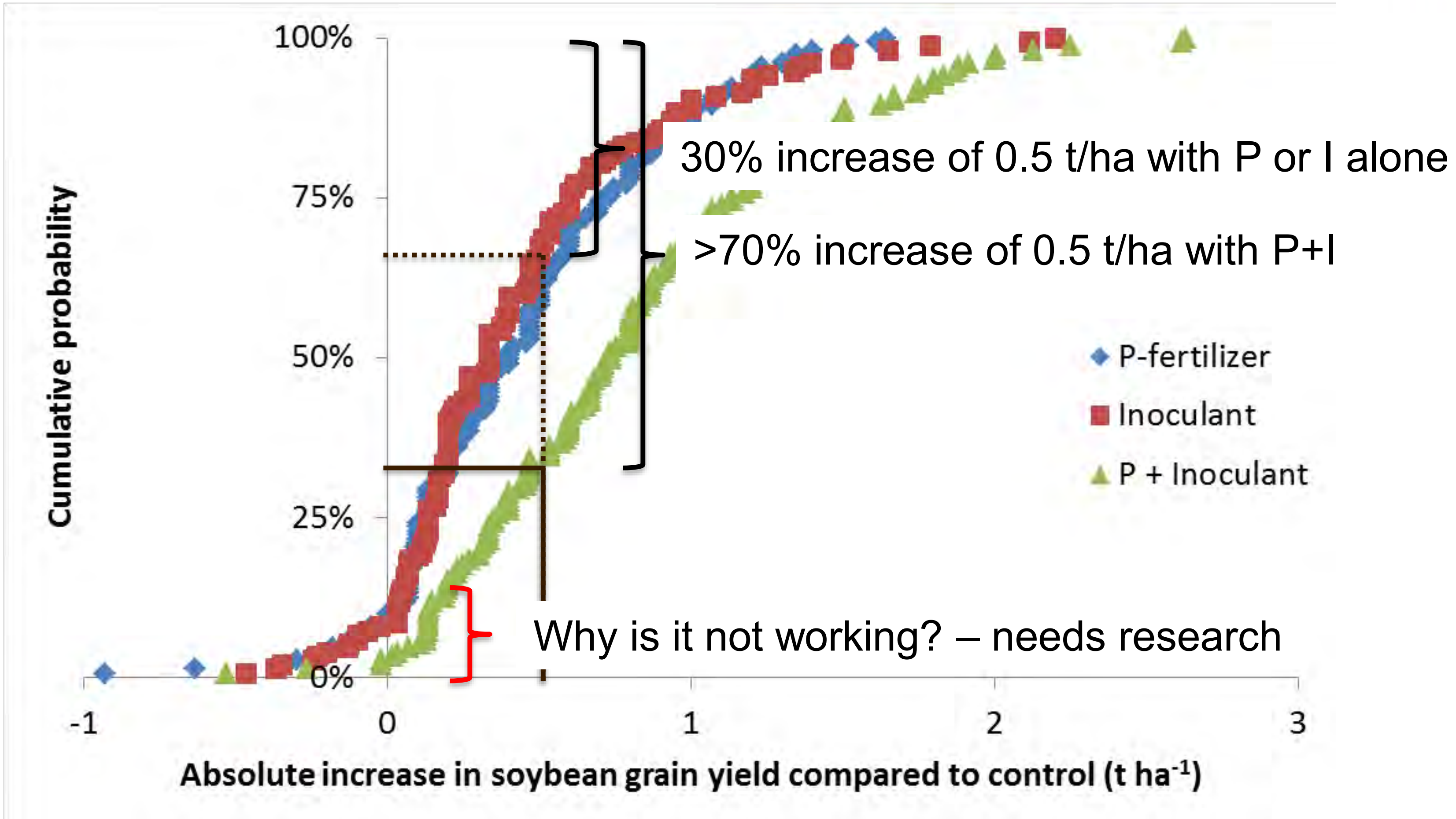
Effect of Inoculant and/or P-fertilizer on soybean grain yield (t ha^{-1}) in Nigeria, 2011 and 2012



Mean effects (kg/ha)	
+P+I	**1745**
+P	1420
+I	1415
Control	968
SED	48

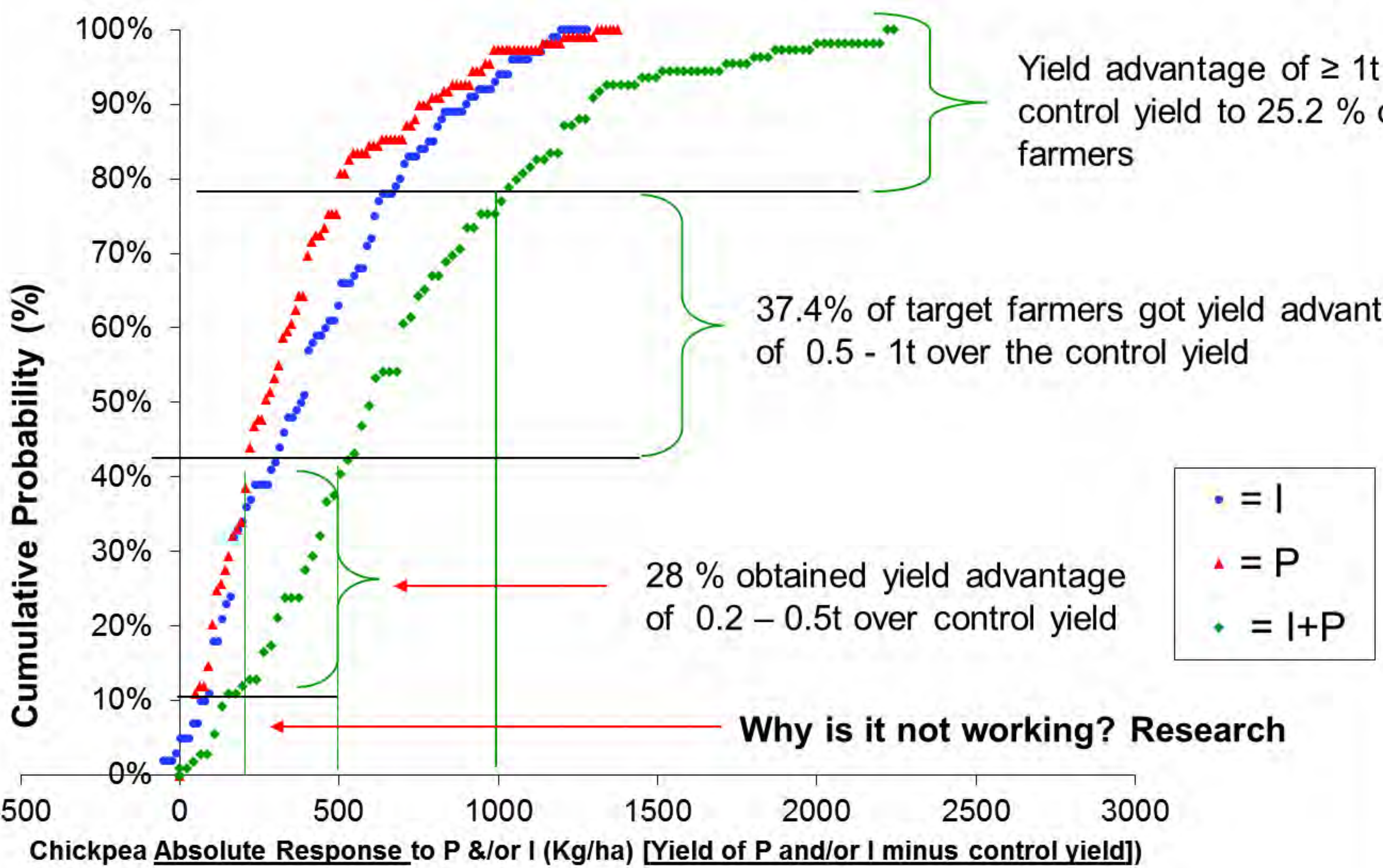
Ronner *et al.* (2016) *Field Crops Research*, 186, 133-145.

Cumulative probability of increase (t ha^{-1}) in soybean grain yield compared with control, Nigeria, 2011 and 2012



Ronner *et al.* (2016) *Field Crops Research,* 186, 133-145.

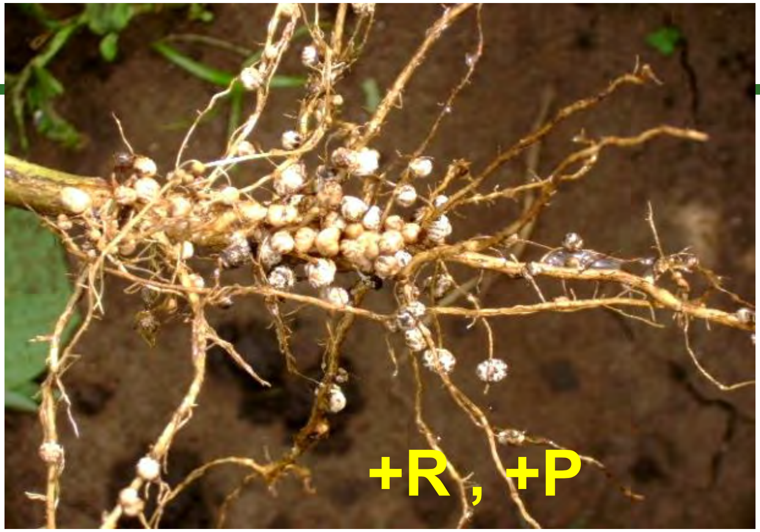
On farm chickpea yield increase with I+P evident for most of the smallholder farmers, Ethiopia 2012 - 2015

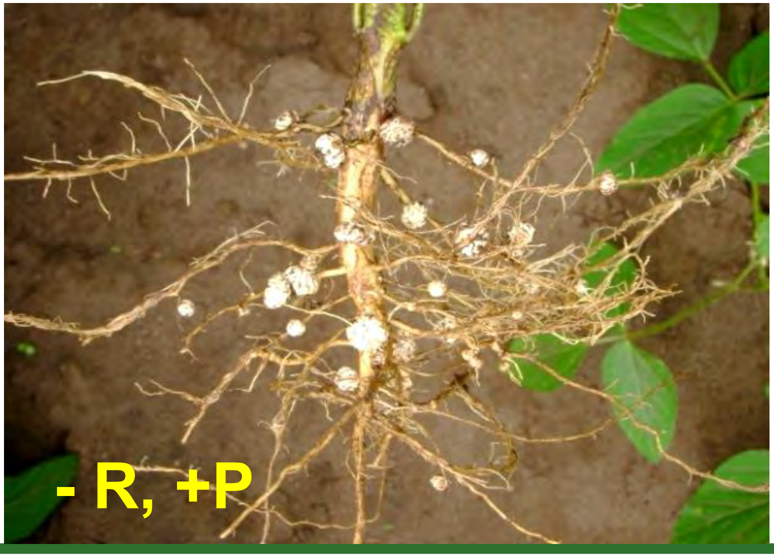


Non-responsive soils

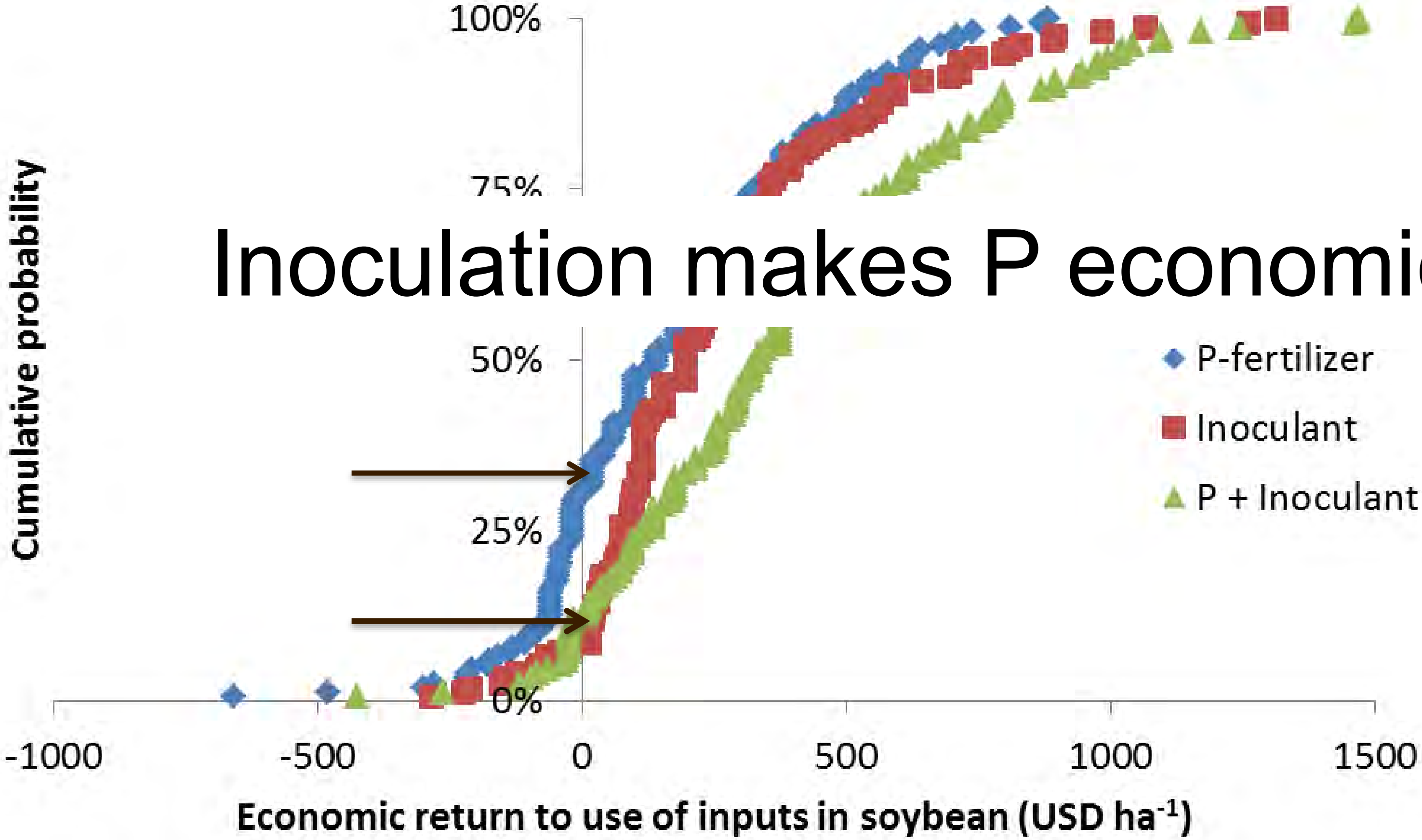
Pot experiments - Nigeria

Inoculation and P application on Soybean, Gofa, Ethiopia





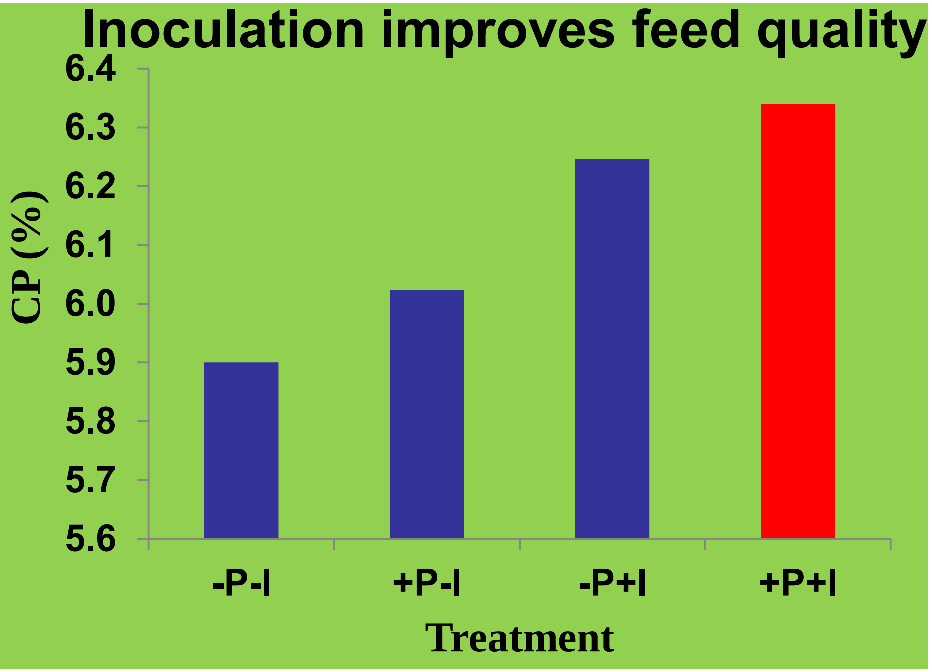
Cumulative probability of economic return to use of inputs in soybean (US$ ha^{-1}) in Nigeria, 2011 and 2012



Inoculation makes P economic!!

Ronner *et al.* (2016) *Field Crops Research,* 186**,** 133-145.

Inoculation enhances the nutritional quality in legumes residue



Partnerships: A model for sustainability and institutionalization

The four project pillars

Stakeholders' capacity development on impr… legume technologie… agribusiness, gend… mainstreaming, legu… value addition and nutrition

Input demand …

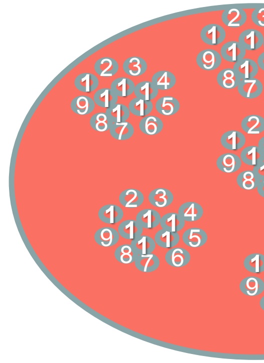
Delivery of proven …

Bulking and pulling …arketable surplus, …ngthening collective …ting, linking with lead … and stimulate home …nsumption as an alternative

The PPP – for largescale dissemination of the technology

Inputs
- **Inoculant**
- **Chemical Fertilizer**
- **Improved Seeds**
- **Agro chemicals**

?



Smallholders (produce

- **Buyers**

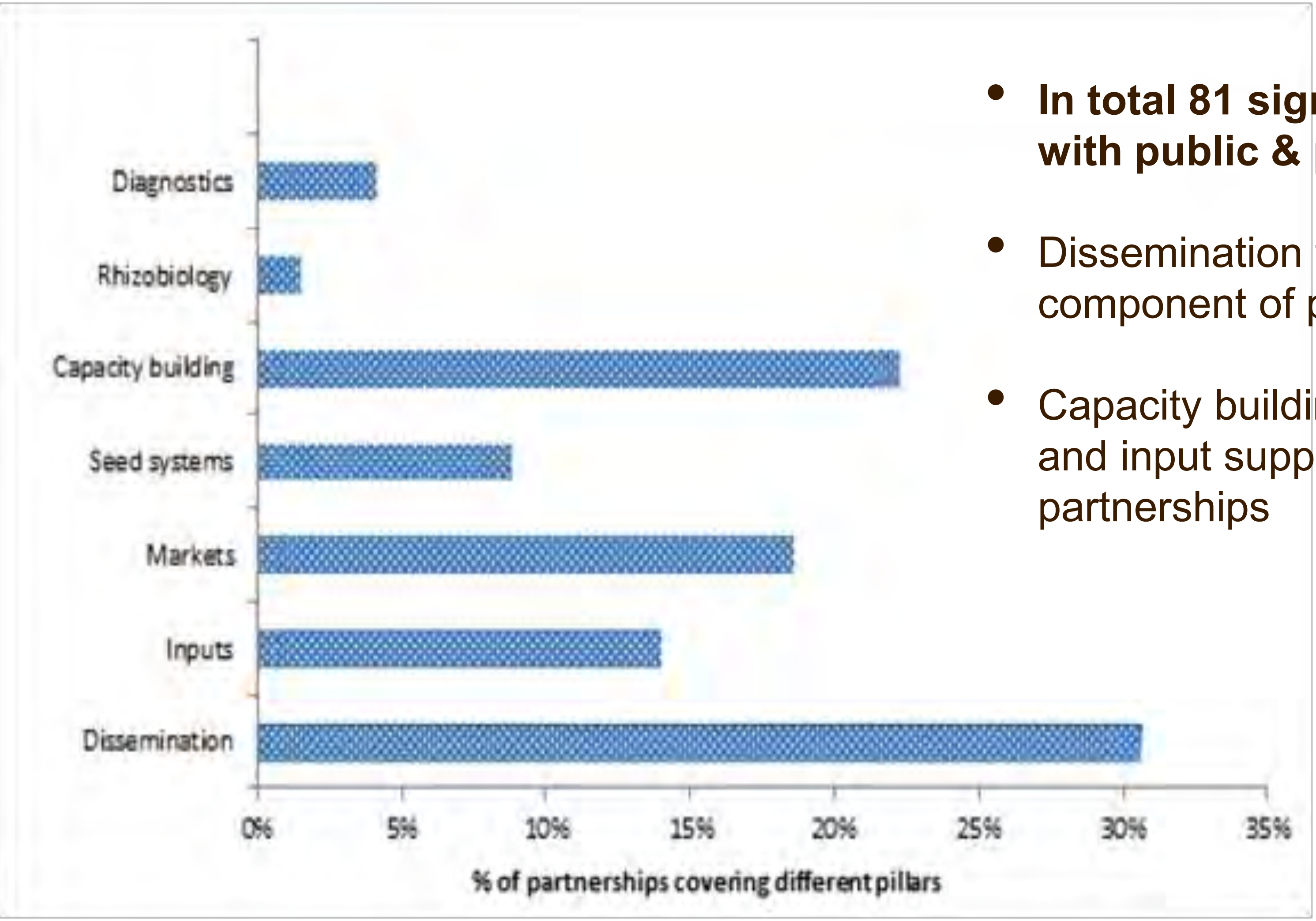
The nucleus farm, *Balegreen Spice and Grain Development*, pioneered

- Mechanizing chickpea farming and breaking prolonged cereal mono-cropping
- Out-grower arrangement with 23,000 smallholder farmers to grow Kabuli chickpea
- Stimulated legume technology scale up through
  - Strengthened seed system development
  - Serve as last mile delivery for inoculants from MBI
  - Grain bulking and delivery to ACOS for the Monino Kabuli variety

ILRI / N≡N	IQQO	Balegreen	Menagesha Biotech	ACOS Agricultural Commodity Supplies
Designing Facilitation Technical support M&E Grants	Trainings Dissemination Research M&E Extension/aiding materials	Seed production Input supply Dissemination & scale up Extension services, Bulking and delivery	Inoculant production and supply Inoculant handling and application	Basic seed Grain sourcing/Exporting Trainings on grain quality and grading

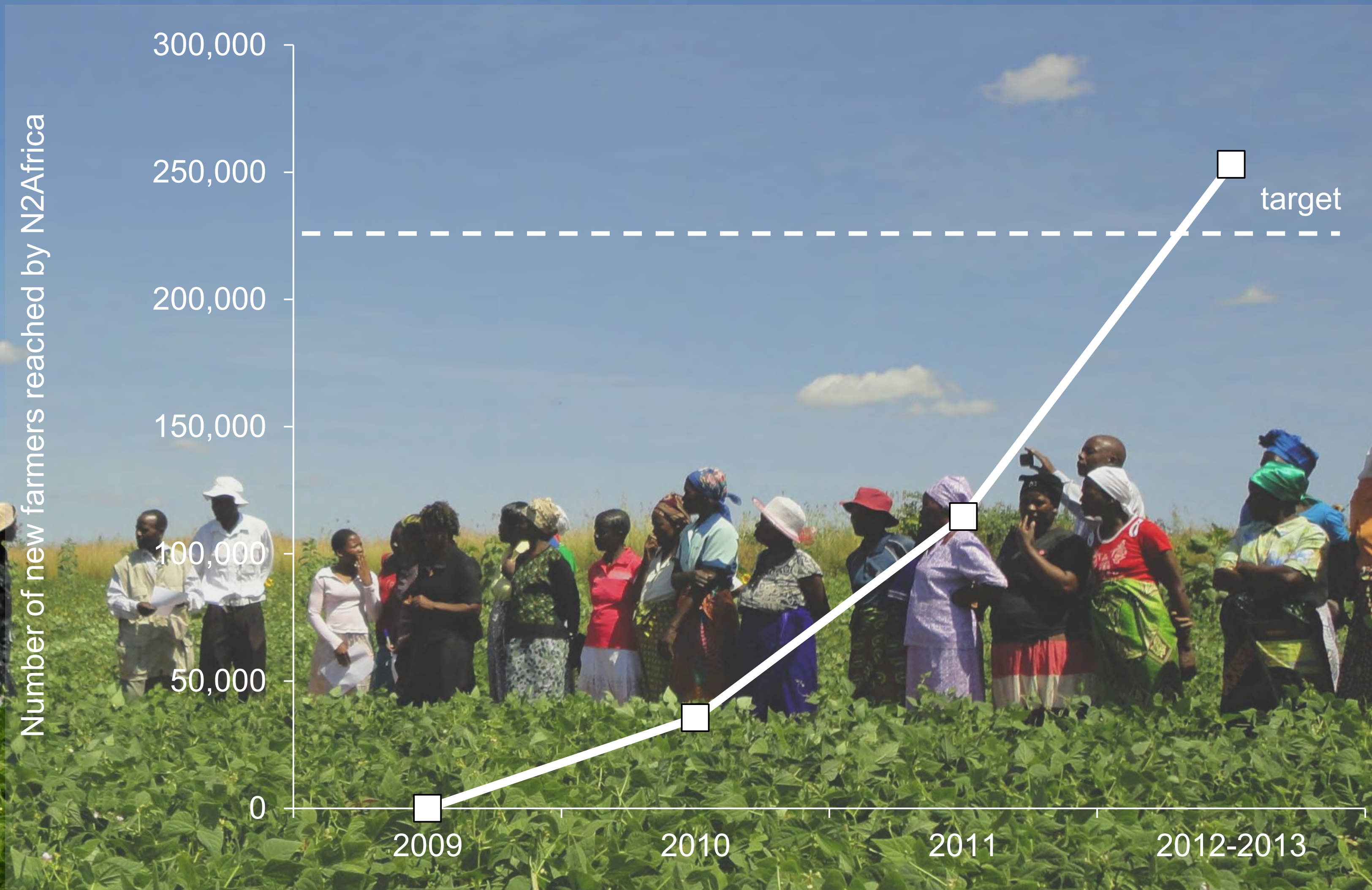
Role mapping and overview of the South-East Public-Private Partnership Cluster

Partnerships - components covered



- **In total 81 signed partnerships with public & private partners**
- Dissemination forms major component of partnerships
- Capacity building, output markets and input supply integral in most partnerships

- N2Africa Phase I - Large scale dissemination of legume technologies to 225,000 farmers
- Phase II targets 600,000 farmers



For updates

www.N2Africa.org

- Lots of video resource materials
- N2Africa Podcaster - Monthly Newsletter
-

THANK YOU