Advancing Sustainable and Healthy Food Production Systems through the Application of Quality Rhizobia Inoculants

Seminar on Organic Research Webinar Organized by the Finnish Organic Research Institute

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Experts engaged in work package 3 (WP3) for sustainable food production systems

HealthyfoodAfrica (HFA) Project, WP3

- Prof. Kristina Lindström, UH
- Prof. Sirkku Juhola, UH
- Dr. Aregu Aserse, UH

- Prof. Enyew Adgo, Bhir Dar University, Ethiopia
- Mr. Victor Yakubu, Tamale, Ghana

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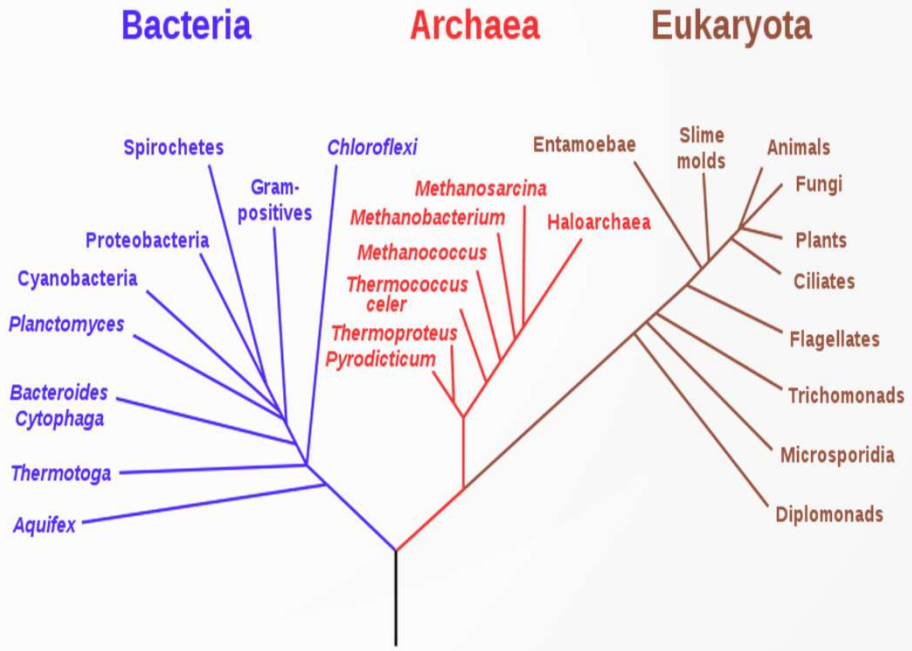
Biological nitrogen fixation (BNF)

BNF-the process by which atmospheric nitrogen (N_2) reduced to ammonia by certain groups of Bacteria and Archaea, $N_2 + 8[H] \Leftrightarrows 2NH_3 + H_2$

- Alpha- and betaproteobacterial species, rhizobia
- Actinobacterial genus, Frankia
- Cyanobacteria
- Free-living bacteria **and Archaea**



https://en.wikipedia.org/wiki/Three-domain_system

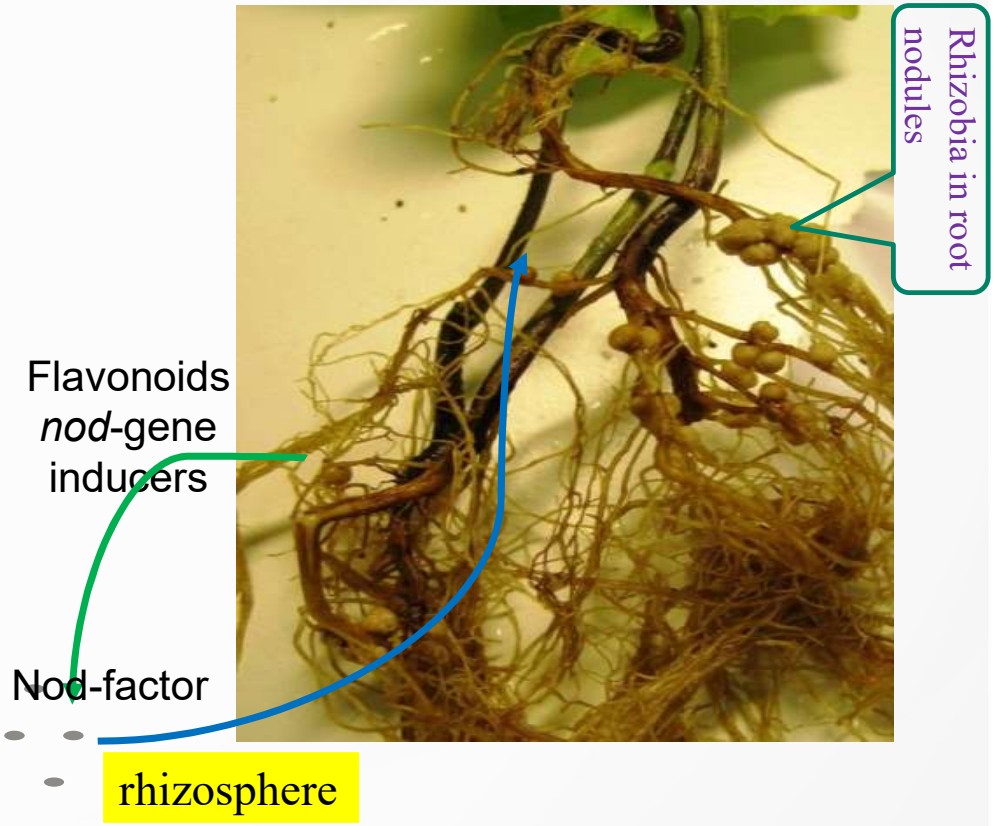
Lindström et al, 2015. Evolution and Taxonomy of Nitrogen-Fixing Organisms with Emphasis on Rhizobia, https://doi.org/10.1002/9781119053095.ch3

Biological nitrogen fixation (BNF)

Cyanobacteria-Plant Symbioses

Cyanobacteria makes symbiotic associations with Azolla, an aquatic fern. Azola is mainly applied on farms as an organic N source to increase rice productivity.
http://theazollafoundation.org/azollas-uses/in-rice-production/

Rhizobia – Legume symbioses



The role of legumes and BNF in farming systems

- Food legumes are the main **protein sources** for African Smallholders
- Used for green manuring and cover crop to improve soil health
- Legumes in rotation/intercrop with cereals improves soil fertility

✓ E.g. Mean yields of maize grown after soybean in Malawi were **3.5 t ha^{-1}** compared with **2.5 t ha^{-1}** in maize after maize (van Vugt et al., 2018)

- Rhizobia inoculants are cost-effective and environmentally friendly N sources
- **BNF plays a significant role in climate mitigation**

✓ N is fixed with a substantially **lower greenhouse gas footprint** than fertilizer N
✓ BNF => minimize surplus N => Minimize N_2O emission, potent GHG

Factors affecting BNF/Rhizobia-legume symbiosis

BNF ~ (GL × GR) × E×M

– GL = the legume genotype;
– GR = the rhizobia genotype
– E = the environment
– M = management

- **Environment;** temperature, soil types, and nutrients
- Indigenous rhizobia inoculants are better adapted to local conditions
- **Acidic soil** usually restricts rhizobia growth, nodulation and N fixation

- **Management**; agronomic practices like sowing and inoculation dates
- Rhizobia **are specific** in their symbiotic partners, the legumes
- Rhizobia **strains vary in** their N fixation ability

Identification of effective N-fixing rhizobia inoculants

N fixation test in the greenhouse in 2014, UH

Characterization

- Basic Microbiology
- Soil Microbiology
- Molecular biology
- Bioinformatics

Non-inoculated (left) and inoculated (right) common bean plants

Soybean nodulation test

Identification of effective N-fixing rhizobia inoculants

Testing the inoculants in the field conditions in Ethiopia

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Rhizobial inoculation improves drought tolerance, biomass and grain yields of common bean (*Phaseolus vulgaris* L.) and soybean (*Glycine max* L.) at Halaba and Boricha in Southern Ethiopia

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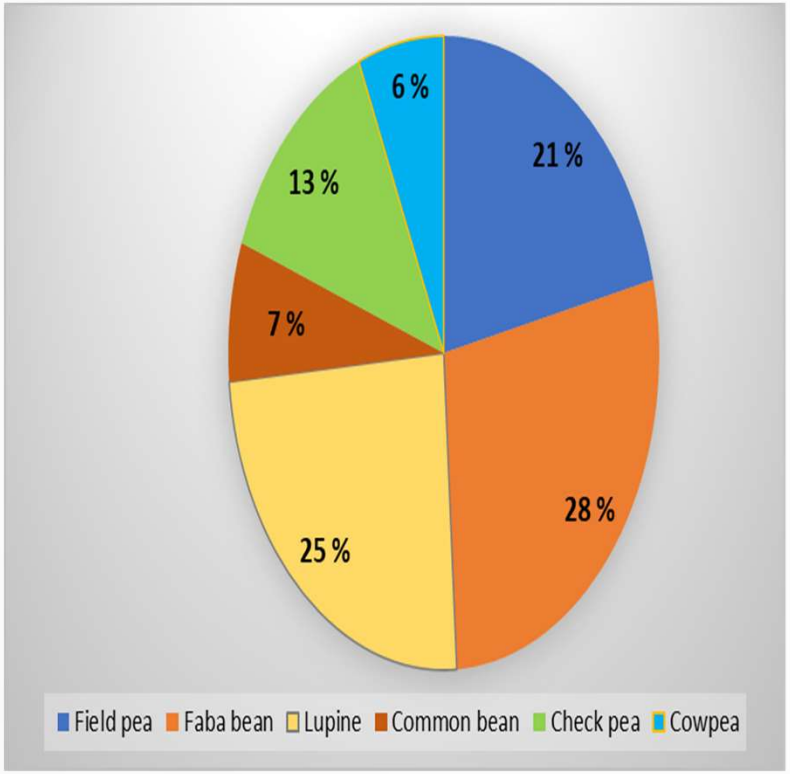
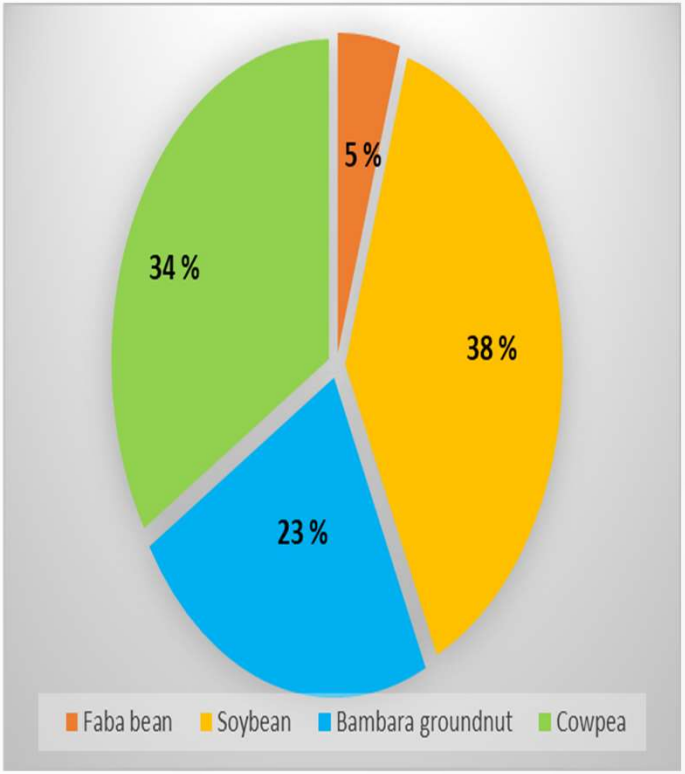
- Rhizobia improved plant drought tolerance
- Inoculated legumes gave biomass and grain yields equivalent to plants receiving N-fertilizer
- Strains **HAMBI3570 and HAMBI3562** were the best inoculants for common beans

Common food legumes/pulses growing in Ethiopia and Ghana, HFA project

Diverse grain legume species are known to grow in the sub-Saharan region.





Pulse legumes grown around food system labs(FSLs), Bahir Dar in Ethiopia (left) and Tamale, Ghana (right)

Challenges in food legume production systems in Africa

- **Soil acidity** and low fertility, leading to low agricultural productivity
- **Unsustainable farm Practices**, usually mono-cropping systems

- High fertilizer prices

- **Low rhizobia inoculants accessibility**, only 10 % to 18 % had **access**
- **Low awareness**, limited knowledge of inoculant use in farming communities

✓ **Limited quality culture collections**, facilities to scale up inoculant production

✓ **Administrative Challenges**, lack of focus in promoting inoculation practices

Piloting sustainable food legume production systems Bahir Dar, Ethiopia

- Training on quality inoculant production and legume inoculation methods

✓ Lab experts, scientists, and extension workers at FSL-BDU in 2021, 2022
✓ A new microbiology and inoculant-producing lab is being built at FSL-BDU

- Field trails with inoculated common bean, in 2022, 2023

- Expert from UH produced rhizobia inoculants for the field experiments and for interested farmers

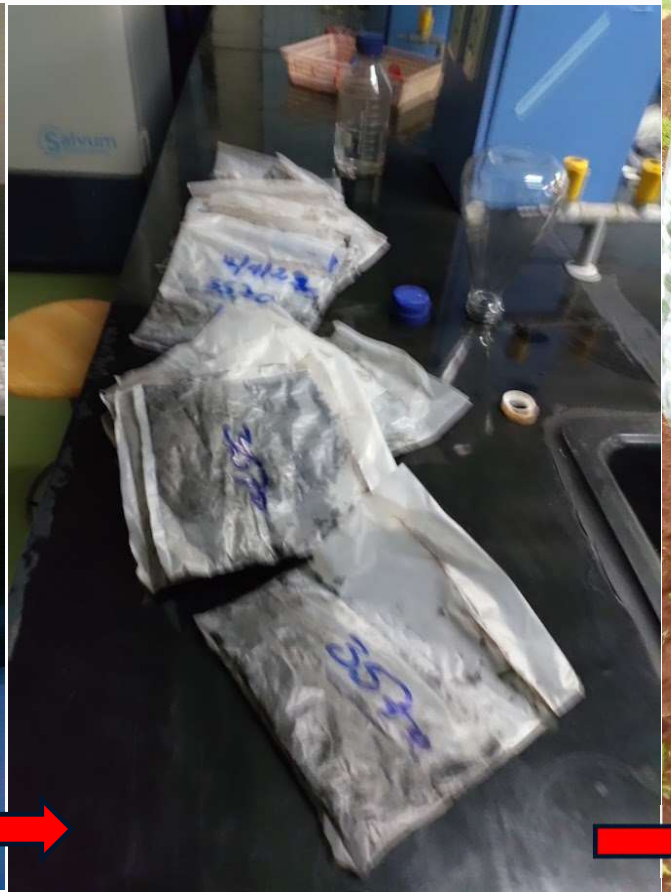
Piloting sustainable food legume production systems, Bahir Dar

Rhizobia inoculant preparation and seed inoculation, 2022

Rhizobia

HAMB13570

HAMBI13562



Rhizobia broth culture (left), rhizobia mixed with peat (middle), seed inoculation (right), Bahir Dar, Ethiopia

Piloting sustainable food legume production systems, Bahir Dar

Common bean planting date at field site, Bahir Dar, 2022

Treatments

1. Control

2. rhizobial sitrains
   HAMB13570
   HAMBI13562

2. Starter N (10kg, 20kg/ha)

3. Lime (2 ton/ha)

L0S0R0 (control)

L0S0R2(Rhizobia HAMB13570)

L0S2R2(Starter N 20kg, HABB13570)

L1S2R0(lime 2 ton, N 20 kg)

L1S0R2(lime 2 ton, HAMB13570)

L1S2R2(lime 2 ton, N 20kg, HAMB13570)

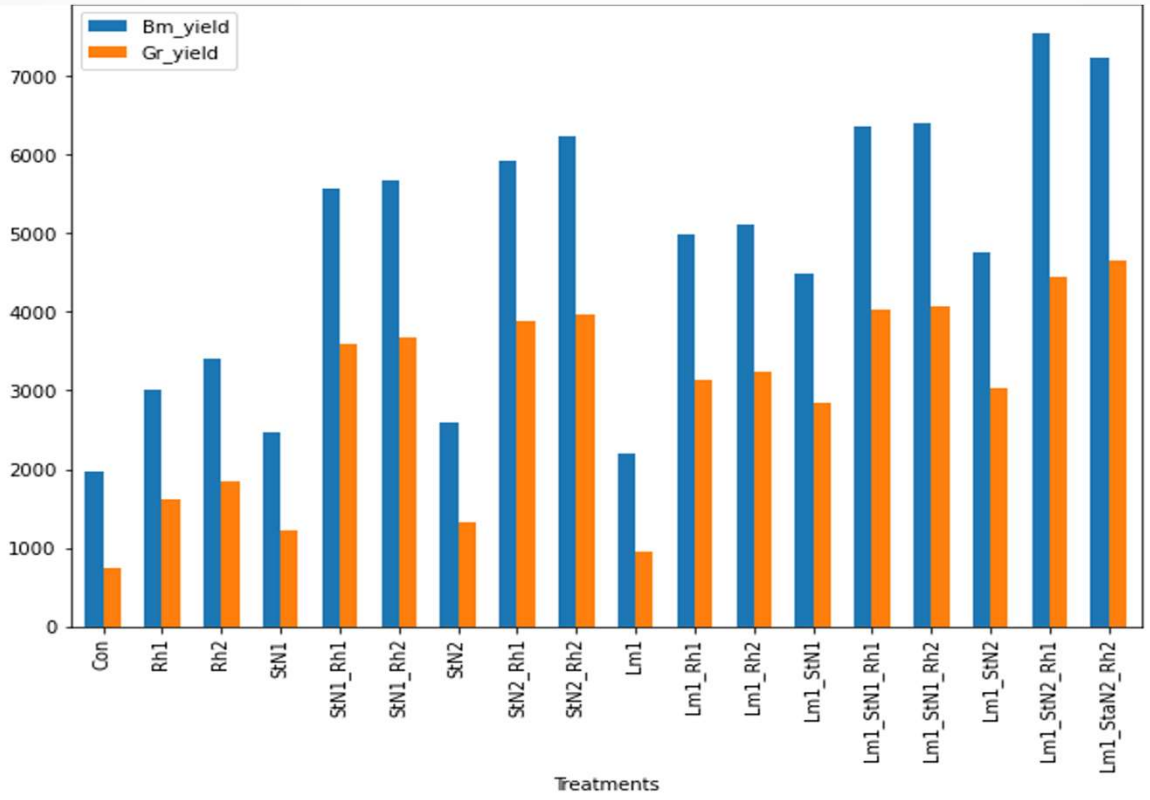
Piloting sustainable food legume production systems, Bahir Dar

Local farmers' field visit to inoculated-bean plants

- Farmers were introduced to bean plots with different treatments
- Farmers were asked to choose best performing bean plots

Piloting sustainable food legume production systems, Bahir Dar

Biomass and grain yield results of common bean plants



Con: Control, Rh1: HAMBI3570, Rh2: HAMBI3562, StN1: StarterN 10 kg N/ha, StN2: StarterN 20kg N/ha, Lm: Lime 2 t/ha.

Piloting food legume production systems in Tamale, Ghana

Soybean inoculation practiced by women farmers

Rhizobia inoculants were **produced by Savanna Agriculture Research Institute**, Tamale

Piloting food legume production systems in Tamale, Ghana

Training on soybean production to women groups, 2021

Discussion 9th April 2023

Piloting food legume production systems in Tamale, Ghana

- Soybean inoculation was done in 2021, 2022, 2023
- **Rhizobia inoculant boosted soybean grain yields**

✓ On average inoculated soybean yielded 500 kg/acre, but without rhizobia 300 kg/acre => **66% increase**

- Empowering women farmers and school-feeding caterers

✓ Training on soybean and indigenous vegetable processing for Diverse Diets

Field Officer visit to soybean farms

Main findings and lessons learned from food legume inoculation practices

- Field trial outcomes highlight the importance of liming acidic soils for optimal rhizobia inoculant performance and achieving a substantial increase in grain yields.

- Women farmers achieved a substantial increase in **soybean yields** through inoculation, resulting in improved income and the diversification of family food resources with various soybean diets.

✓ The **inoculation success and the field demonstrations increased** interests among local farmers in rhizobia inoculation and legume production in both Bahir Dar and Tamale.

✓ The news about ecologically sustainable food-legume production with rhizobia inoculants is now spreading to a wider farming community in Ethiopia and Ghana.

Thank you for your Attention