Enhancing biological nitrogen fixation (BNF) of leguminous crops grown on degraded soils in Uganda, Rwanda, and Tanzania. II. Physiology Studies

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Issues Being Addressed:

Common beans are the most important legume food crop in Uganda, Rwanda, and Tanzania providing about 38% of utilizable protein and up to 16% of the daily caloric requirement. Yields on small-landholder farms, however, are a typically only a fraction of the crop's genetic potential due in part to the unmet requirement for N. Although common beans roots are host for a range of soil rhizobia species, they are relatively poor Nitrogen fixers (typically less than 50 lbs per acre), which is far less than needed for optimal growth. We are conducting physiology and microbial studies to understand the limitations to Biological Nitrogen Fixation (BNF) in common beans. Among the physiological parameters being examined in this poster are root vs. shoot control of nodulation in phaseolus, and the population of indigenous nodule-forming rhizobia in the degraded Host Country soils where field trials on inoculation response are being conducted.

Objectives:

1. Determine whether root factors or shoot factors control the extent of nodulation in common beans varying in capacity for N-fixation.
2. Quantify effective levels of nodule forming rhizobia in soils at field research sites used to test bean yield response to local and Biostacked® inoculant.

Approach:

Reciprocal grafts between roots and shoots of selected lines varying in capacity for nodule formation were evaluated under greenhouse conditions. These included self grafts, cross-variety grafts, and across species grafts. Once grafted plants were established, soil was saturated with Becker Underwood **BioStacked®** inoculum to promote nodule formation. At flowering, samples were collected for shoot/root basis, tissue N and ureide concentration, and nodulation score. Within-species nodulation and biomass data are presented here.

Relative levels of 'effective rhizobia' in soils at field trial locations were assessed by quantifying nodulation response to soil solution inoculation. Trapping genotypes were A55: a Type IIa Middle American (MA) black bean, G122 (PI 163120): a Type I Andean bean, and Othello: a widely adapted pinto bean cultivar. Seeds were surface sterilized and planted in sterilized vermiculite. At 3, 5, and 6 weeks, each pot received 10 mL half-strength N-free Hoagland solution. At 4 weeks, each pot received 10 mL of soil solution in at dilution rates ranging from 10^{-1} to 10^{-4} with 4 reps per variety x soil x dilution. Nodulation response was assessed at 8 weeks. Data were analyzed using the Most Probable Number Calculator.

Table 1. Comparison of "effective rhizobia populations" in soils collected from field research sites in Host Countries and US (number g^{-1} soil). Othello, A55, and G122 represent Middle American, Andean, and pinto bean cultivars, respectively.

Soil Source	Othello	A55	G122	Average
Kamuli, Uganda	8	0	3	**3 e**
Morogoro, Tanzania	210	550	91	**284 d**
Selian, Tanzania	200	1600	350	**717 c**
Kigali, Rwanda	79	340	340	**253 d**
Musanze, Rwanda	48	11000	41	**3696 a**
Rubona, Rwanda	9	2	0	**4 e**
Nyagatere, Rwanda	240	3800	2400	**2147 b**
Patterson, USA	63	810	20	**298 d**
Average	**107 b**	**2263 a**	**406 b**	

Results:

Grafted plants prior to transplanting. Common bean: center Soybean: left and right

A) Puebla 152 root system B) Eagle root system

Genetic variation in rooting evaluated in grafting studies

Grafted bean plants just prior to flowering

Figure 1. Nodule number on roots of bean lines used for grafting studies. PIR32, Eagle, and Puebla 152 were selected based on their varying capacity for BNF. R99 is a non-nodulating line.

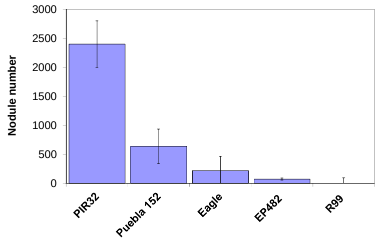


Figure 2. Nodule number on roots of grafted plants using the non-nodulating line R99 as the rootstock or scion. Many nodules formed on PIR32, Eagle, and Puebla 152 roots with R99 as the scion.

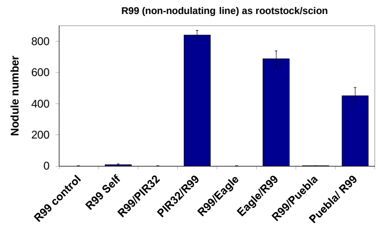


Figure 3. Root biomass of grafted plants using the non-nodulating line R99 as the rootstock or scion. Nodule number was correlated with root biomass mass in nodule-forming grafts. Scion did not effect root biomass of R99.

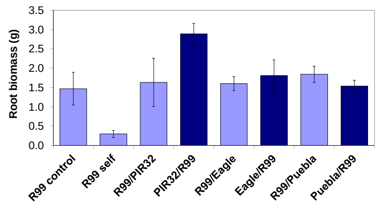
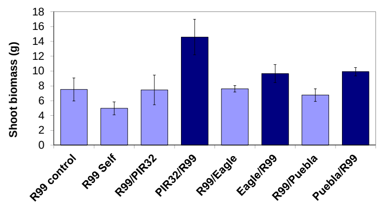


Figure 4. Shoot biomass of grafted plants using the non-nodulating line R99 as the rootstock or scion. Nodule forming grafts accumulated more shot biomass. Scion did not effect shoot mass of R99.



Conclusions/opportunities:

Large variation exists in indigenous soil rhizobia levels capable of forming N-fixing nodules, even within Research Station Sites. **Variation on farms could be equally dramatic and pose a primary limitation for N-fixation. Variation in host receptivity also could limit N-fixation in locally adapted cultivars.**

Grafting results with non-nodulating R99 as a scion clearly indicate root factors regulate nodule formation in this line. This is contrary to well-documented regulation of super-nodulation by the shoot. **Evidently, both root and shoot factors need to be considered in attempts to enhance nodule formation and effectiveness on rhizobia poor soils.**

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