Enhancing biological nitrogen fixation (BNF) of leguminous crops grown on degraded soils in Uganda, Rwanda, and Tanzania. I. Field Trials

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Issues Being Addressed:

Common beans are the most important legume 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 are a small fraction of the crop's genetic potential. Low levels of BNF are a primary limitation. In these studies, we are examining interactions between inoculant source, bean variety, and field conditions in managed field trials. Field trials were conducted at National Research Stations in diverse agro-ecological zones in Uganda, Rwanda, and Tanzania. Yield response, yield components, environmental conditions, rhizobia counts, and nodulation were evaluated at each location. In this poster, we present soil analysis and yield data from these trials.

Objectives:

1. Evaluate yield response of improved bean varieties to locally-produced and stacked inoculants (i.e. Becker Underwood BioStacked®) in controlled field trials.
2. Identify environmental and biological constraints to enhancing BNF of inoculated plants.

Approach:

Field trials were established at the ISAR Research Station in Nyagatare Tanzania, the NaCCRI Research Stations at Namulonge, Mbarara, and Kabale Uganda, and the SUA Research Stations at Morogoro and Selian Tanzania. Bean varieties released by local breeding programs were inoculated with inoculants produced at Makerere University (MAK/Biofix), Nairobi (NBO), SUA (NitroSUA), or Becker Underwood (USA/BioStacked®). Soil samples were analyzed for nutrient content and rhizobia counts. Plants also were sampled mid-season for biomass, N content and nodule scores. Only the soil and yield data are presented in this poster.

Results:



Table 1: Effect of inoculant treatment on bean yield at Namulonge (low altitude) and Mbarara (medium altitude) sites in Uganda, 2011. Mak = Mak-Bio-fixer Inoculant, USA = Becker Underwood Inoculant, NBO = Bio-N-fix Inoculant, Con = no inoculation

Site	Variety	Inoculant			
		Mak	USA	NBO	Con
			(kg/ha)		
Namulonge	K132	569	372	347	654
	Kanyebwa	556	508	406	453
	K131	671	775	1030	817
Mbarara	K132	1900	1867	1278	1256
	Kanyebwa	2033	2100	2133	1633
	K131	1744	1994	1449	1822
$LSD_{0.05}$			398		
CV (%)			42		

Table 2. Soil analysis from Research sites in Tanzania, Rwanda, and Uganda in 2011. Data highlighted in yellow are of some concern, and likely reduce yield potential. Data highlighted in red are of extreme concern and should be addressed directly to improve yield potential and nitrogen fixation potential. Most sites had pH less than 6.0. Rubona's soil pH of 4.3 is certain to limit nitrogen fixation. Kamuli soil has extremely low available phosphorus. Rubona and Musanza soils were very low in Boron. Boron is needed in greater amounts by nitrogen-fixing crops.

yellow: some concern
red: extreme

town	country	pH 1:1	E.C. 1:1 nmhos/cn	NO3-N mg/kg	NH4-N mg/kg	OM %	P mg/kg	K mg/kg	Ca meq/100g	Mg meq/100g	Na meq/100g	S mg/kg	B mg/kg	Zn mg/kg	Mn mg/kg	Cu mg/kg	Fe mg/kg	Eff.	A&E pH	REQ T/Ac	Al mg/Kg
Nyagatere	Rwanda	5.8	0.50	13.6	16.0	3.2	15	349	4.6	1.8	0.14	43	0.61	1.6	323.1	3.0	133	0	7.3	1.5	0.9
Rubona	Rwanda	4.3	0.56	33.0	19.6	2.3	31	187	0.9	0.4	0.12	66	0.02	0.3	301.1	2.4	205	0	7.1	3.6	55.5
Musanza	Rwanda	5.7	0.53	29.6	19.3	2.1	33	130	3.4	0.6	0.20	16	0.13	1.7	78.9	1.2	29	0	7.5	1.2	3.2
Selian	Tanzania	6.9	0.37	2.8	16.0	3.8	32	1700	13.1	3.4	0.44	32	0.55	6.5	320.1	8.3	32	0	7.2	0.0	0.8
Morogoro	Tanzania	5.9	0.57	15.5	19.9	3.9	15	382	4.9	3.8	0.39	39	0.41	2.3	323.1	2.2	44	0	7.3	1.4	1.0
Kamuli (Vedco	Uganda	6.2	0.41	9.2	13.9	3.1	5	284	4.8	1.7	0.22	29	0.24	4.5	323.1	2.3	24	0	7.5	0.6	2.6
Kampala	Uganda	6.4	0.68	17.2	15.1	3.6	16	248	5.4	1.5	0.15	43	0.27	5.3	320.1	3.3	31	0	7.5	0.0	2.5
	value too:	low		RURW, MURW high			low	MURW low				low	low	low			high				high
				SETZ low				SETZ high													
	ideal:	6.5	< 2	25			20+	200	1.2	0.4	<0.35	30	1	1	4	0.8	10				

Table 3: Effect of inoculant treatment on bean yield of climbing varieties at Kabale (high altitude) site in Uganda, 2011. Same abbreviations as in Table 2.

Variety	Inoculant			
	Mak	USA	NBO	Con
		(kg/ha)		
Land race	667	378	407	559
NABE10c	593	569	235	230
NABE12c	399	469	557	594
$LSD_{0.05}$		187		
CV (%)		49		

Table 4. Effect of rhizobium and P on bean yield of two climbing and two bush bean varieties at ISAR Nyagatare research station in Rwanda, season 2011A. BU = Becker Underwood, Ken = University of Nairobi, NoR = Control.

Inoculant Treatment	P (kg/ha)	Mac49 – C (kg/ha)	MAC44 – C (kg/ha)	SER16 – B (kg/ha)	RWR1668 – B (kg/ha)
BU+	20	1500	1125	1125	1188
BU+	0	1188	1250	1250	750
Ken+	20	938	1000	1688	1188
Ken+	0	1000	1188	1313	1188
NoR	20	1438	1000	1250	1188
NoR	0	1313	938	438	1063

Table 5: Yield of bush beans grown at the SUA research station at Morogoro, Tanzania. Seed were inoculated with one of three rhizobia inoculants, with or without 20 kg/ha P. 2011A. Similar results were observed at the Selian-Arusha site.

	VARIETY	BIOFIX	BIOSTACKED	NITROSUA	CONTROL	Mean
				(kg/ha)		
Po	Bilfa-4	535	455	591	433	**504**
	Kablanketi	303	354	299	314	**318**
	Rojo	741	667	920	937	**816**
	Jesca	499	553	556	451	**515**
	BAT 477	108	123	124	105	**115**
	Mean	**437**	**424**	**498**	**448**	**452**
P+	Bilfa-4	377	569	527	616	**522**
	Kablanketi	323	350	353	394	**355**
	Rojo	675	834	741	881	**783**
	Jesca	724	436	585	557	**576**
	BAT 477	132	133	87	95	**112**
	Mean	**446**	**464**	**459**	**509**	**469**
	LSD			**117**		
	CV (%)			**44**		
	SE			**58**		

Conclusions/Opportunities:

•There was considerable variation in bean yield within and across research sites. The response to inoculation also was variable with no discernible response in many cases. **Much greater control of field trial conditions will be needed to resolve local limitations to BNF.**

•All locations had one or more chemical characteristic likely to reduce bean productivity and nitrogen fixation. **Nitrogen fixation is unlikely to be significant at sites with extreme soil issues, regardless of seed inoculation.**

•Soil analyses and related trapping studies also revealed considerable variation in rhizobia strains and nodulation (See project poster on Physiology studies). **Soil chemical and physical limitations need to be controlled to resolve the soil biological limitation to BNF.**