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PhD Student Special

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Introduction

This special issue of the N2Africa Podcaster is devoted to updates from each of the PhD students being funded through N2Africa. Dr Amaral Chibeba from Mozambique is the only student to have completed his PhD so far, although we expect several more to complete in the coming months. Your comments and suggestions on the ongoing projects are most welcome.

Ken Giller

Dotting the i's and crossing the t's in Kenya

Picture 1. (a) Screening strains for effectiveness on bean in the greenhouse, (b) data collection and (c) images of ineffective and effective bean nodules

My research project has assessed the diversity and symbiotic effectiveness of bacteria nodulating beans in different agro-ecological zones in Kenya, developed a gene-marker system for rapid analysis of nodule occupancy and evaluated the effect of several factors, such as soil nitrogen, on strain nodule occupancy outcomes.

I am currently working on the final draft of my PhD thesis in preparation for submission for examination within the month. Details of my research findings will appear in a future bulletin.

George Mwenda, Murdoch University, Australia (Click here for his 2015 update)

Exploring the genetic diversity of groundnut-nodulating rhizobia in moist and dry savannas in Nigeria for increased symbiotic nitrogen fixation and productivity

The aim of my study is to unravel the types, nature, genetic diversity and effectiveness of groundnut-nodulating rhizobia existing in different soil types of the moist; northern Guinea (NG) and dry; Sudan (S) savannas of Nigeria, with a view to identify strains that hold promise for improved symbiotic N_2-fixation, productivity and soil fertility. After the last report of my studies in 2015 (Podcaster 32), there have been significant progress and fascinating findings with regard to the genetic diversity of groundnut-nodulating rhizobia. The 32 novel groundnut-nodulating rhizobia strains from the Nigerian NG and S savannas, isolated in the course of my PhD study, were subjected to RPO1 finger printing (Richardson *et al.*, 1995). Overall, the results showed very high genetic diversity among the strains.

Eleven representatives of the novel Nigerian indigenous groundnut-nodulating rhizobia strains were selected, based on growth of the strains on YMA media and subjected to 16S rDNA sequencing, which further confirmed the strains' genetic diversity, earlier shown by the RPO1 finger printing. Over 90% of them are *Bradyrhizobium* strains, all closely matching (query cover 98-100% and identity 99-100%) with varying species deposited in the genebank. The strains were tested for effectiveness in the glasshouse on an Australian groundnut cultivar (Kangaroy peanut). The results indicated compatibility and high effectiveness of the strains on the cultivar, indicating their potential for adoption as commercial inoculant strains within Nigeria and beyond.

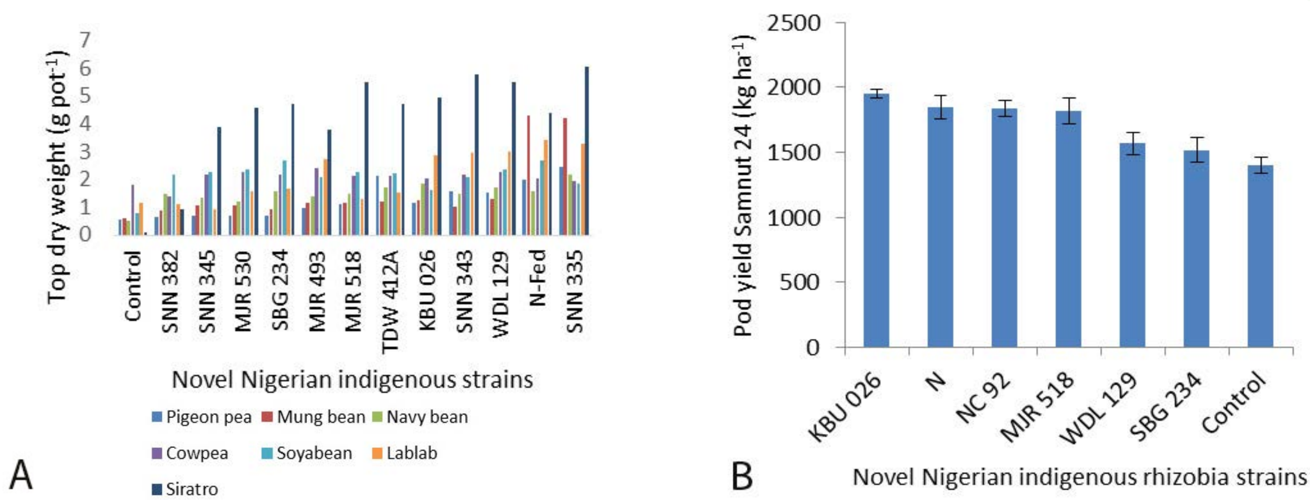


Figure 1. (A) Interaction between the eleven representatives of the Nigerian indigenous rhizobia strains and seven host legumes in top dry weight (g pot^{-1}) relative to uninoculated control and (B) combined performance of selected novel Nigerian indigenous rhizobia strains in both northern Guinea and Sudan savannas of Nigeria, as tested in the research farms of the Institute for Agricultural Research, Ahmadu Bello University, Zaria Nigeria at Samaru and Minjibir during the 2015/2016 growing season

Furthermore, the strains were subjected to host range studies on seven legume hosts; navy bean (*Phaseolus vulgaris* L.), mungbean (*Vigna radiata*), soyabean (*Glycine max*), siratro (*Macroptilium atropurpureum*), pigeon pea (*Cajanus cajan* Millsp), cowpea (*Vigna unguiculata*) and lablab (*Lablab purpureus*). These host range studies were conducted to test the level of promiscuity among the strains and the legume hosts. The results showed high level of promiscuity among both the strains and the legume hosts. Most of the strains effectively nodulated with all the legume hosts. The exception was navy bean, which was nodulated by all the strains, but none was effective. SNN 382 did not nodulate siratro, mungbean and pigeon pea. This strain also had the least influence on top dry weight of the legume hosts (Figure 1A). Significant interaction was observed between the strains and the hosts in top dry weight (g pot^{-1}), relative to the uninoculated control (Figure 1A).

Field experiments in the Nigerian NG and S savannas, the original environments from which the strains were isolated, using four of the strains which have been confirmed effective in earlier reported glasshouse and field experiments (Abdullahi *et al*., unpublished but presented in Podcaster 32), indicated KBU 026 to be the best among the strains, with mean pod yield of 1,953 kg ha^{-1} obtained from combined analysis of data for both the NG and S savannas. The strain performed significantly better than the N-fed control (20 N kg ha^{-1}), all other strains (including NC 92) and the uninoculated control (other competing native rhizobia strains in the field) (Figure 1B). This shows the high potential of the strains, particularly KBU 026 for adoption as an inoculant strain. I am currently in Nigeria and at high stage of my thesis writing, in contact with my supervisors, hoping to complete my studies as soon as possible.

Aliyu Anchau Abdullahi, Murdoch University, Australia

Reference: Richardson, A. E., Viccars, L. A., Watson, J. M. and Gibson, A. H. (1995). Differentiation of Rhizobium strains using the polymerase chain reaction with random and directed primers. *Soil Biology and Biochemistry 27* (4/5), 515-524.

Genetic and symbiotic effectiveness of indigenous rhizobial strains and strategies to maximize the contribution of biological nitrogen fixation on soyabean in Mozambique

Genetic and symbiotic characterization of indigenous rhizobia

The objectives of this study were to characterize indigenous rhizobia and to identify strains that hold potential to be included in inoculants for soyabean production in Mozambique. Rhizobia isolates were sampled from promiscuous soyabean varieties at 15 locations and were taken to Brazil. A total of 105 isolates were screened for symbiotic effectiveness in the greenhouse along with four strains used in inoculants in Brazil, *Bradyrhizobium japonicum* SEMIA 5079, *B. diazoefficiens* SEMIA 5080, *B. elkanii* strains SEMIA 587 and SEMIA 5019, and one strain used in Africa, *B. diazoefficiens* USDA 110. The genetic and symbiotic characterization were based on the 87 isolates that nodulated the non-promiscuous soyabean cultivar BRS 133 in the screening experiment. The genetic analyses were based on BOX-PCR profiling of the genomic DNA and 16S rRNA gene sequencing. BOX-PCR analysis revealed great genetic diversity with a total of 41 phylogenetic groups found and the 16S rRNA gene sequencing analysis clustered the 87 isolates in *Bradyrhizobium* (75%) and *Agrobacterium – Rhizobium* (25%) clades.

In relation to symbiotic effectiveness, great variability was detected among the native rhizobia from Mozambique with 10 isolates performing better than USDA 110, the best reference strain, and 50 isolates with lower performance than all the reference strains. Thirteen of the best performing isolates were selected for a second greenhouse experiment with two promiscuous (TGx 1963-3F and TGx 1835-10E) and one non-promiscuous (BRS 284) soyabean varieties and the five reference strains. Five isolates consistently exhibited superior symbiotic effectiveness suggesting that the inoculation of soyabean with indigenous rhizobia adapted to local conditions is strategic for soyabean production in Mozambique. Multi-location field experiments with those promising isolates will be conducted to ascertain their superiority in fixing N_2 in the presence of other indigenous and/or commercial strains.

Feasibility of transference of inoculation-related technologies from Brazil to Mozambique

To study the feasibility of transferring inoculation-related technologies from Brazil to Mozambique, the elite rhizobia strains used in the previous experiments were tested in field experiments conducted with non-promiscuous soyabean genotypes in Brazil (four sites) and Mozambique (five sites) in the 2013/2014 and 2014/2015 crop seasons. The best inoculation treatments across sites and crop seasons in Brazil were SEMIA 5079, SEMIA 5080 and USDA 110, with average grain yield gains of 4–5% in relation to the non-inoculated (NI) treatment. SEMIA 5079, SEMIA 5080, SEMIA 5019 and USDA 110 were the best performing strains in Mozambique, with average 20–29% grain yield gains over the NI treatment. These results suggest the feasibility of transference of inoculation-related technologies between countries with similar agro-climatic conditions.

Co-inoculation of soyabean with *Bradyrhizobium* and *Azospirillum*

The objective of this study was to ascertain the effect of co-inoculating soyabean with *Bradyrhizobium* and *Azospirillum* on the precocity of nodulation. The study was first conducted in the greenhouse and the successful result was confirmed in the field. In both experiments, conducted in Brazil, co-inoculated soyabean nodulated precociously, suggesting that the presence of *Azospirillum* helps plants to overcome environmental stresses.

Conclusion and recommendation

High genetic and symbiotic diversity was detected among the indigenous rhizobia from Mozambique. Five isolates consistently showed high N_2-fixation effectiveness, suggesting that inoculation with rhizobia adapted to local conditions is a possible strategy for soyabean production

Figure 1. Amaral Chibeba (center) and from left to right, Dr. Maria Guimarães (UEL – Brazil, Supervisor), Dr. Adriana da Silva (UEL – Brazil, Thesis Evaluation Panel Member), Dr. Steve Boahen (IITA – Mozambique and N2Africa, Supervisor), Dr. Mariangela Hungria (Embrapa – Brazil, Supervisor), Dr. Felix Dakora (Tshwane University of Technology – South Africa, Thesis Evaluation Panel Member) and Dr. Marco Nogueira (UEL – Brazil, Thesis Evaluation Panel Member)

in Mozambique. Multi-location field experiments should be conducted in Mozambique to confirm the performance of those strains.

In the two-season field experiments conducted in Brazil and Mozambique, strains SEMIA 5079, SEMIA 5080 and USDA 110 showed great potential to be included in inoculants in both countries. The results confirm the feasibility of transference of inoculation-related technologies in soyabean between countries with similar agro-climatic conditions.

USDA 110 was the best reference strain in the greenhouse experiments and had an excellent performance in the field experiments conducted in Mozambique and Brazil, including at Londrina where this strain was inoculated for the first time and there was a rhizobial population of over 10^5 cells g^{-1} of soil. Interestingly, some indigenous isolates from Mozambique had similar or better performance than USDA 110 in the greenhouse experiments, which opens a window of research opportunities with those rhizobia.

I successfully defended my thesis in June 2016 (Figure 1).

Amaral Machaculeha Chibeba, State University of Londrina (UEL), Brazil (Click here for his 2015 update)

Examining indigenous soyabean rhizobia populations for inoculant use in Zimbabwe

Rhizobia inoculants form the backbone of soyabean production, which is important in Zimbabwe's agriculture led economy. Traditionally, soyabean production is carried out with the use of elite, but exotic, rhizobia inoculant strains. It has been established in previous studies (Zengeni *et al.*, 2003; Zengeni *et al.*, 2006) that these strains do not persist well in the fields, and require frequent inoculation. Poor rhizobia survival is due to low levels of clay, organic carbon and soil fertility. In my study, I was prospecting for indigenous strains as we hypothesised that they are adapted to the Zimbabwean agro-climatic conditions and therefore persist. The first aim was to find strains that are comparable to the exotic strains with respect to nitrogen fixation capacity. I isolated a total of 137 authenticated soyabean nodulating isolates from contrasting agro-climatic and management conditions. I compared them for nitrogen fixation against each other under glasshouse conditions at Murdoch University, Australia. I identified strains that are efficient in nitrogen fixation and could replace the exotic inoculant strains in future.

Secondly, I examined the diversity of the indigenous soyabean nodulating rhizobia population in Zimbabwe, using molecular methods as well as standard comparisons on culture media on the isolates obtained in the study (see Podcaster 32). Culture morphology generated two major groups with subgroups within, while molecular characterizations revealed four *Bradyrhizobium* species.

Another study in 2015 was carried out to develop a method to identify the rhizobia strains. Evaluation of host range across a specific range of legume hosts provided some insight into species identity (Figure 1). Additionally, I developed a rapid molecular method to identify strains as part of quality assurance and control during inoculant production.

All this experimental work was carried out at Murdoch University between 2012 and 2015, after which I returned to work at the Soil Productivity Research Laboratory in Zimbabwe. I continue writing my thesis and look forward to submitting it and using the new elite indigenous rhizobia from my study for soyabean production in Zimbabwe.

Strain	NAZ 505	NAZ 519	NAZ 641	NAZ 661
Species identity	*B. japonicum*	*B. ottawaense*	*B. diazoefficiens*	*B. elkanii*
Soyabean (*Glycine max*)	E	E	E	E
Mung bean (*Vigna radiata*)	-	E	I	-
Sunnhemp (*Crotalaria juncea*)	-	E	-	E
Common bean (*Phaseolus vulgaris*)	-	I	-	I

Figure 1. Host range evaluation helped to distinguish between four *Bradyrhizobium* species identified in Zimbabwean soils

Mazvita Chiduwa, Murdoch University, Australia

References:
Zengeni, R., Mpepereki, S. and Giller, K.E. (2003). *Survival and persistence of introduced commercial rhizobial inoculant strains in selected smallholder field environments of Zimbabwe. Grain Legumes and Green Manures for Soil Fertility in Southern Africa: Taking Stock of Progress,* SoilFertNet and CIMMYT-Zimbabwe, Harare, Zimbabwe, pp. 53-56.
Zengeni, R., Mpepereki, S. and Giller, K.E. (2006). Manure and soil properties affect survival and persistence of soyabean nodulating rhizobia in smallholder soils of Zimbabwe. *Applied Soil Ecology, 32*, pp. 232-242.

Response of groundnut (*Arachis hypogaea* L.) varieties to rhizobia inoculation in the Sudan and northern Guinea savannas of Nigeria

The aim of my study is to explore the use of rhizobia inoculation in order to increase yield and biological nitrogen fixation of the selected groundnut genotypes in the Sudan and northern Guinea savannas of Nigeria. Last year, I have already started the field work with two experiments. The first experiment included the following treatments; six groundnut varieties and six different inoculants treatments (NC 92, SBG 234, MJR 518, WDL 129, +N (20 kg N ha^{-1}), and -N (0 kg N ha^{-1})). The second experiment included sixteen groundnut varieties and three inoculant treatments (NC 92, +N (20 kg N ha^{-1}), and –N (0 kg N ha^{-1})).

Picture 1. From left to right: Dr Kamai, my project coordinator, Dr Abdelaziz, my IITA adviser, Dr Babu from ICRISAT and myself during one of their visit to my field in Bayero University Nigeria

Picture 2. Showing my visitors round in the groundnut fields in Bayero University, Nigeria

Results of the first experiment showed that variety significantly influenced the growth and yield of groundnut in the two locations. Inoculant was only significant on shoot dry weight with SBG 234 (281.4 kg ha^{-1}) showing the highest recorded weight and followed by MJR 518 (281.1 kg ha^{-1}) in northern Guinea savanna +N (209.0 kg ha^{-1}) had the highest recorded weight in Sudan savanna. SAMNUT 25 resulted in the highest pod yield (1,152.78 kg ha^{-1}) in the northern Guinea savanna and KWANKWASO (2,575.62 kg ha^{-1}) in the Sudan savanna (details are presented in the N2Africa Annual Review and Planning Meeting Abuja 2016 Report). The results of second experiment followed similar trends, as I presented in the poster during Joint Pan-African Grain Legume and World Cowpea Conference in Zambia, 2016. I have started repeating the first experiment in order to confirm my previous observations.

Faruk Galadanchi Umar, Bayero University, Nigeria. (Click here for his 2015 update)

Assessment of improved cowpea varieties cultivated by women farmers in southern part of Borno State, Nigeria

This study examined the impact of improved cowpea varieties on the income and the food security status of women farmers in southern part of Borno State, Nigeria. The study used data on farmers before the Promoting Sustainable Agriculture in Borno State (PROSAB) project started in 2004 and after the project folded up about ten years after in 2015. The study specifically aimed at describing the socio-economic characteristics of women cowpea farmers in the study area; identifying the changes in income as a result of using improved cowpea seeds; analysing the impact of the improved cowpea varieties on the food security status; analysing the determinants of technical efficiency; estimating the technical efficiency in using improved cowpea and identifying the constraints associated with the use of improved cowpea varieties by women cowpea farmers.

The results indicated that a large proportion of the respondents (42% participants and 44% non-participants) were within the age group of 31-40 years, were married (68% participants and 75% non-participants) and have average household sizes of 6-8 people (data not shown). On average 66% participants and 62% non-participants were educated (up to tertiary) with mean farm sizes of 1.2 and 0.8 hectares, respectively.

Findings from the Double Difference (DD) estimates (Table 1) showed that the average annual income of the participants increased, suggesting a positive impact on income although other factors such as age, education and marital status may have influenced income. The Cost-of-calorie index (Table 2) showed that, based on the daily energy level of 2,250 Kcal recommended by Food and Agriculture Organization, the food security line per adult equivalent per month was N2,743.81 and N2,076.69 for the participants and non-participants, respectively. The results also showed that 66% of the participants and 33% of the non-participants were food secure.

Table 2. Food security measures among women households in PROSAB area

Variable	Before PROSAB	After PROSAB		
		Participants (n=240)	Non-participants (n=60)	DD
Cost-of-calorie equation	lnX=a + bC	lnX=a + bC	lnX=a + bC	
Constant	4.154 (0.534)*	4.4510 (60.972)*	3.2506 (21.963)*	
Slope coefficient	0.0019 (0.0004)	0.0000144 (12.496)	0.0004221 (16.234)	
FAO recommended daily energy levels (L)	2,260 kcal	2,260 kcal	2,260 kcal	Naira 21.52
Food insecurity line (Z)	Naira 63.71 per day	Naira 88.51 per day	Naira 66.99 per day	Naira 667.12
	Naira 1,975.01 per month	Naira 2,743.81 per month	Naira 2,076.69 per month	-0.3297
Head count (H)	0.58	0.3433	0.673	-33%
Food insecure (%)	58%	34%	67%	-33%
Food secure (%)	42%	66%	33%	
Aggregate income gap (G)	-375.74	-412.43	-783.91	371.48

Source: Field Survey Data (Zongoma, 2015).
* Figures in parenthesis are t-values

The major constraints faced by women cowpea farmers were diseases and pests, high costs of labour and inadequate access to markets. It was recommended that policies should be formulated to encourage women farmers in the study area to adopt and sustain the use of improved varieties of cowpea. Furthermore, women farmers in the study area should be given adequate enlightenment on how to control pests and diseases and improved cowpea varieties and other inputs should be made readily available and accessible to the women farmers at affordable prices, on time and in adequate quantities.

Table 1. Average annual household income (Naira) from cowpea before and after the PROSAB project

	Before PROSAB	After PROSAB	Difference	Difference	Double Difference	T-Value
	(Naira)	(Naira)	(Naira)	(%)	(DD) (Naira)	
Participants	56,004.80	199,500.00	143,495.20	256.20	84,995.20	8.43***
Non-Participants	31,000.00	89,500.00	58,500.00	188.70		

Source: Field Survey Data (Zongoma 2015).
*** Significant 1%

Binta Ali Zongoma, University of Maiduguri, Nigeria (Cick here for her 2015 update)

Comparing yields and some yield components of common bean from intercropping and rotations with maize in the northern highlands of Tanzania

The aim of my study is to unravel the contributions of genetic, environmental and management related factors to common bean yield and nitrogen fixation. I am conducting a continuous cropping study, which involves rotations and intercropping of common bean with maize for six seasons and compare the performance of two bean varieties; namely improved *Lyamungu 90* and local *Mkanamna*.

After three consecutive cropping seasons, long–short–long seasons, for 2015–2015/2016–2016 mean bean yield (t ha^{-1}), number of pods per plant and number of seeds per pod were compared (Table 1). The mean number of pods per plant and seeds per pod indicated that local bean *Mkanamna* outperformed *Lyamungu 90*. This could be attributed to the differences in their genotypes and formation of many branches in local bean.

The yield of *Lyamungu 90* significantly (P <0.05) outperformed yield of local bean *Mkanamna* during the first and second cropping season. Under sole cropping during the 2015 long and short rainy seasons, the mean yield of *Lyamungu 90* was 4.373 t ha^{-1} and 3.195 t ha^{-1}. Those of

Table 1. Mean yield (t ha^{-1}), pods per plant and seeds per pod of *Lyamungu 90* and local bean *Mkanamna* compared for three consecutive cropping seasons in sole cropping and intercropping with maize

Treatments		Measured variables								
		Pods per plant			Seeds per pod			Mean yield (t ha^{-1})		
2015 long rainy season	2015/16 short rainy season	2015 Long	2015/16 Short	2016 Long	2015 Long	2015/16 Short	2016 Long	2015 Long	2015/16 Short	2016 Long
Ly90 sole	Ly90 sole	7.1ab	2.625a	3.925ab	2.051ab	2.229a	2.250a	4.373c	3.195cd	1.667ab
Sole maize	Ly90 Rot in m	N/A	3.02a	N/A	N/A	2.337a	N/A	N/A	3.298d	N/A
maize + Ly90	m+Ly90 cont	6.787ab	2.53a	2.800a	1.799a	2.062a	2.268a	3.139b	2.632ab	0.158a
m+Ly90 Rot	Sole maize	7.437ab	N/A	5.280b	1.994ab	N/A	2.127a	3.509bc	N/A	0.559a
Lb sole	Lb sole	15.137c	6.885b	7.635c	3.086ab	2.159a	4.080a	3.65bc	2.718abc	3.338bc
Sole maize	Lb Rot in m	N/A	6.1b	N/A	N/A	2.511a	N/A	N/A	3.067bcd	N/A
Maize+local bean	m+Lb cont	6.875ab	4.73ab	7.340c	3.874b	2.559a	3.585a	2.037a	2.331a	1.477ab
m+Lb Rot	Sole maize	13.275bc	N/A	7.470c	3.912b	N/A	4.242a	3.604bc	N/A	1.062a
	SE±	2.842	1.332	0.976	0.835	1.021	1.056	0.419	0.2241	0.868
	$LSD_{(0.05)}$	5.91	2.838	2.014	1.737	2.175	2.178	0.871	0.4776	1.791
	P – value	0.025	0.017	<.001	0.056	0.995	0.168	0.001	0.004	0.001

Key: *Ly90=Lyamungu 90, Ly90 Rot in m = Lyamungu 90 grown after maize, m+Ly90 cont = continuous cropping of intercropped Lyamungu 90, Lb=local bean, Lb Rot in m = Local bean grown after maize, m+Lb cont = continuous cropping of intercropped local bean; N/A = Not applicable. *Means along the same column sharing the same letter do not differ significantly at 5% level of probability based on the least significance difference (LSD).*


Eva Thuijsman, MSc student Wageningen University, assisting Eliakira Kisetu in measuring chlorophyll content in the experimental plots using SPAD in Hai district, Tanzania


Eva Thuijsman holding a camera supported at the top with a rod for easy taking photos on ground coverage in the experimental plots in Hai district, Tanzania


Eva Thuijsman taking data on light interception using a light meter in the experimental plots in Hai district, Tanzania


Gladness Pius Lema, a trained casual labour, assisting Eliakira Kisetu in counting bean grains at harvest in Hai district, Tanzania

Picture 1. Measurements of chlorophyll content, ground coverage, light interception and counting bean grains local bean *Mkanamna* were lower, 3.650 t ha^{-1}, 2.718 t ha^{-1}, respectively. Mean yield dropped to 1.667 t ha^{-1} for *Lyamungu 90* and decreased to 3.338 t ha^{-1} for local bean *Mkanamna* during the 2016 long rainy season, as compared to the 2015 long rainy season. Intercropping of maize with beans resulted in a higher *Lyamungu 90* yield. The yield of *Lyamungu 90* was 3.139 t ha^{-1} and 2.632 t ha^{-1} and the mean yield of local bean *Mkanamna* was 2.037 t ha^{-1} and 2.331 t ha^{-1} during the 2015 long and short rainy seasons. Under rotations of sole maize with pure beans, the yield of *Lyamungu 90* (3.298 t ha^{-1}) was superior to those of local bean (3.067 t ha^{-1}) for the measurements taken during the 2015 short rainy season. When intercrops of beans and maize were grown continuously, the yields of *Lyamungu 90* were 3.139 t ha^{-1}, 2.632 t ha^{-1} and 0.158 t ha^{-1}, while those of local bean *Mkanamna* were 2.037 t ha^{-1}, 2.331 t ha^{-1}, and 1.477 t ha^{-1} for the three cropping seasons. In rotating intercrops of maize and beans with sole maize, the data taken during the 2015 and 2016 long rainy seasons indicated that the yields of local bean *Mkanamna* were 3.604 t ha^{-1} and 1.062 t ha^{-1}. These were superior to yields of *Lyamungu 90* recorded during similar cropping seasons, which were 3.509 t ha^{-1} and 0.559 t ha^{-1}, respectively.

However, *Lyamungu 90* yield declined significantly (P =0.001) during the 2016 long rainy season, during which local bean *Mkanamna* outperformed *Lyamungu 90*. The reasons for these are not yet clear, but it could be that *Lyamungu 90* yields better, when rain is adequate. Furthermore, there was extended drought during 2015/2016 cropping season, hence entirely irrigation was used. Delayed rains, heavy short-time rains, drought with shortage of irrigation water, and ability of local bean *Mkanamna* plants to delay flowering, hence avoidance of flower abortion, were also observed. On the other hand, there was substantial lodging of *Lyamungu 90* plants compared with local bean *Mkanamna plants*.

Measurements related to the amount of light intercepted, chlorophyll content, plant height and ground coverage were taken (Picture 1). The results of these measurements will be used to explain the observed differences in performance of beans and maize in mono-cropping and intercropping.

Eliakira Kisetu Nassary, Wageningen University, The Netherlands (See here for his 2015 update)

Co-design and implementation of improved climbing bean technologies in Uganda

A lot has happened since last year: the first paper of my PhD, entitled *Understanding variability in soyabean yield and response to P-fertilizer and rhizobium inoculants on farmers' fields in northern Nigeria* got published in Field Crops Research (Podcaster 34), I largely finished the data collection in Uganda and I have entered the final year of my PhD, so I will focus on writing up the results.

I am currently working on my second and third paper. The second paper focuses on the co-design of improved climbing bean technologies with farmers in the eastern and southwestern highlands of Uganda. In 2014 and 2015 we conducted an iterative cycle of co-design of technologies, demonstration of these technologies, and evaluation of the technologies by farmers. Staking was initially identified as main challenge, so in the demonstrations we included alternative, low-cost staking materials: sisal string and banana fibre. We also included tripods, which were expected to enhance yields but were also more labour intensive. In addition, demonstrations involved different climbing bean varieties and inputs (manure, TSP, DAP and their combination), and management practices, such as row planting versus random planting. Different types of farmers (men and women from low (LRE), medium (MRE) and high (HRE) resource endowed households) evaluated these technologies and indicated the criteria that they find important when evaluating a new technology. The evaluations formed the basis for sessions where farmers, researchers, extension officers and NGO staff co-designed treatments for new demonstrations in subsequent seasons. Preliminary results were presented in Podcaster 29. I also

Picture 1. Data collection in field of climbing beans, intercropped with banana and cassava (Kapchorwa, Uganda, 2014)

presented this work during the Farming Systems Design Conference in Montpellier, in September last year (http://fsd5.european-agronomy.org/video/FSD/index.html).

The third paper is about the use and adaptation of climbing beans – how do farmers implement the co-designed technologies in adaptation trials and how do they continue to grow beans one or two seasons after they have participated in the project? In last year's update in Podcaster 32, I presented the results of season 2015A. Currently, I finished the collection of data from three seasons of trials (2014B, 2015A and 2015B) and I am analyzing the results. An important finding from the adaptation trials, consistent over the three seasons, is that farmers in eastern and south-western Uganda often intercrop their climbing beans with banana, coffee or other crops (Picture 1). This could mean that technologies tested and demonstrated in sole cropping could have a different effect when the beans are intercropped. Therefore, we decided to design an agronomy trial in which climbing beans are intercropped with banana. The trial is implemented by the N2Africa team in Uganda this season (2016A). We test the effect of pruning of banana leaves, so that more light is available for the beans, on two different varieties of climbing bean (local varieties *Atama* and *Mubano* versus improved variety NABEIZC). Through co-design of technologies and monitoring of the use of these technologies on farmers' fields, we are able to develop more relevant technologies and recommendations for the diversity of smallholder farmers.

Esther Ronner, Wageningen University, The Netherlands

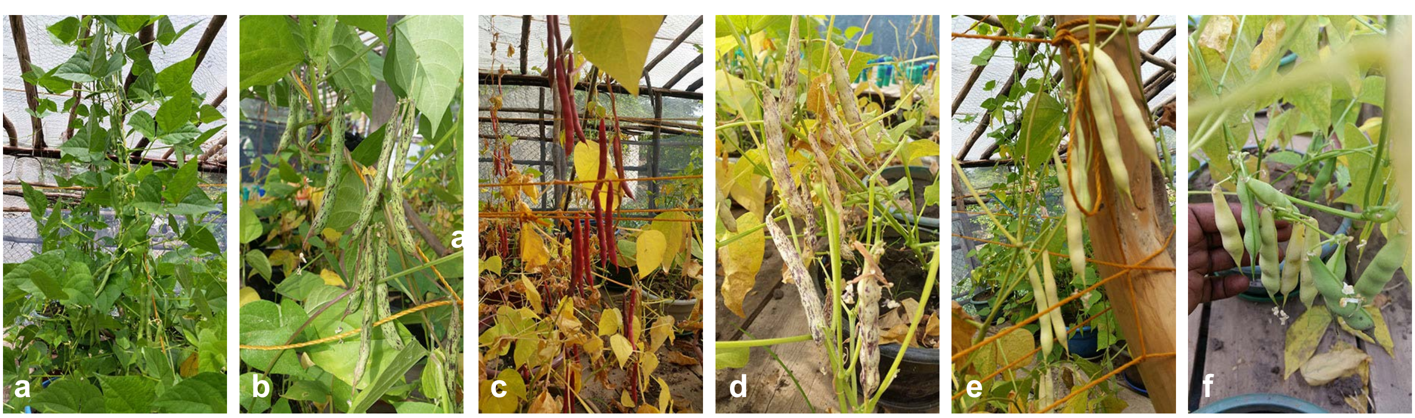
Common bean seed multiplication and isolation of rhizobia nodulating common bean in Ethiopia

Common bean seed multiplication

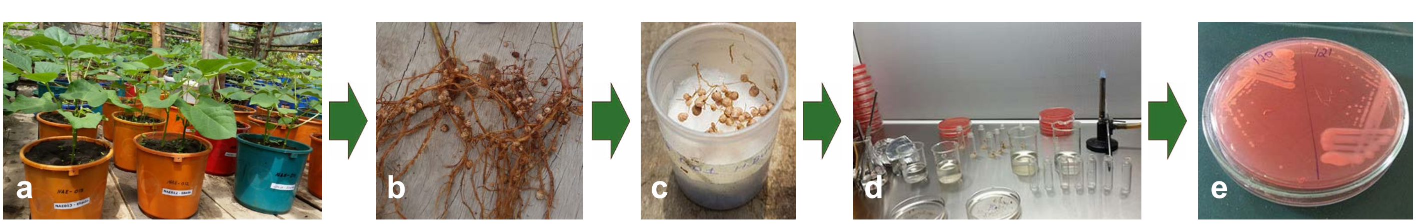
In order to examine the interaction between bean genotypes and rhizobium strains nodulating bean, seed of 29 different bean varieties that represent a great genetic diversity were obtained from CIAT, Colombia. They were multiplied in a screenhouse on soil samples collected from potential bean growing areas in Sidama, Ethiopia.

5 kg of soil samples and 0.5 kg compost were thoroughly mixed, added into pots and well moistened for a week before transplanting germinated seeds. Two seedlings were planted per pot with 5 replications. All replications were kept together and the inner side of the screenhouse was sealed with insect net to avoid insect damage and cross-pollination.

The 29 genotypes had different rates of germination, ranging from 60% to 100%: 19 of them were climbing beans and 10 were bush beans. The maturity status (days from transplanting to harvesting) of the genotypes also varied and some genotypes, such as G20134, G1230, G24482, G19237A, G50545 and G1375, matured early (from April 10^{th}-June 6^{th}) (Picture 1c and d). Others, such as G830, G20141, G764, G11228, G772, G288A, G757, G50123, G8045, G810 and G19833, matured later (Picture 1a and b). Most of the late maturing genotypes among the climbing beans and early maturing ones were both from climbing and bush beans. The genotypes bore between 4 to 21 pods per plant and 1 to 7 seeds per pod. Climbing beans produced more pods per plant.



Picture 1. Common bean genotypes under multiplication: (a and b) Late maturing, (c and d) early maturing and (e and f) maturation in between early and late maturing genotypes



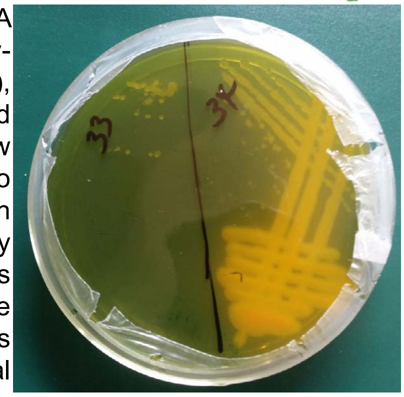
Picture 2. Trapping and isolation of rhizobia from soil (a) trapping rhizobia, (b) nodulation, (c) nodule preserving, (d) nodule surface sterilization and crushing and (e) colonies of isolated rhizobia

Isolation of common bean nodulating rhizobia

Rhizobium strains nodulating common bean were isolated from common bean growing areas of southern Ethiopia to complement the genetic diversity of the strains needed for genotype x genotype interaction study. Soil samples were collected from bean growing farms with history of no inoculation and rhizobia from the soil were trapped by Nasir, Ebado and Hawassa Dume bean varieties (Picture 2a). At the flowering stage the plants were carefully uprooted, nodules were collected and stored in plastic vials on silica gel (Picture 2b and c). Nodulation varied between the varieties and soil sites (data not shown).

Nodules stored on silica gel were imbibed in water for an hour and surface sterilized using 96% ethanol and 2.5-3% sodium hypochlorite according to the methods of Somasegaran and Hoben (1994) and Hungria *et al.* (2016). Surface sterilized nodules were crushed in sterile test tube and the suspension was streaked on Yeast Mannitol Agar containing Congo red (YMA-CR) (Picture 2d).

The isolated bacteria had pale pink colour on YMA-CR with entire margin and slightly raised elevation (Picture 2e). Some of them produced sticky gums, which attach to a loop when touched. On YMA containing bromothymol blue (YMA-BTB), all the strains changed the media into yellow (Picture 3). This was also indicated by their growth on YMA-CR, as they grew within three days after plating out. These cultural characteristics of the isolates are typical features of fast-growing rhizobia.



Picture 3. Strains growing on YMA-BTP

Ashenafi Hailu Gunnabo, Wageningen University, The Netherlands (Click here for his 2015 update)

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Genotype x Environment interaction in soyabean breeding under rhizobia inoculation in the savanna region of Nigeria

Despite the importance of soyabean in Nigeria, yields on farmers' fields have remained relatively low. The crop holds considerable potential for arresting soil fertility decline and enhancing household food nutrition. Therefore, this study aimed to exploit differences among soyabean genotypes, assess genotype environment effect on seed yield and rhizobia inoculation as a means of improving nitrogen fixation and productivity of soyabean across three locations in the savanna region of Nigeria.

24 soyabean genotypes, including five commercial checks, were evaluated across three different agro-ecological zones in northern Nigeria. The inoculants Legume Fix and Nodumax were used in each location. Inoculation was assessed at three levels; without inoculation, Legume Fix and Nodumax. These therefore resulted into 72 (24 x 3) treatment combinations. A split-plot design with 3 replications per treatment was adopted at each location, resulting into 216 (72 × 3) plots. The main plots consisted of the soyabean lines and the sub-plots were the inoculant applications.

Significant differences were observed for all traits except number of leaves and days to 50% flowering. Soyabean grain yield for the 24 genotypes ranged from 1.14 t ha^{-1} – 1.83 t ha^{-1} (Table 1). Grain yield of environments ranged from 1.39 t ha^{-1} in Gwarzo to 2.15 t ha^{-1} in Abuja and was significant in all the three locations, except Gwarzo (data not shown). Inoculation significantly influ-

Table 1. Effect of inoculation treatments on the grain yield (t ha^{-1}) of soyabean genotype

Genotypes	Mean grain yield (t ha^{-1})			LSD
	Without inoculation	Nodumax	Legume Fix	
TGX 1989-11F	1.71	1.89	2.36	313.72
TGX 1990-110FN	1.54	2.13	2.32	468.97
TGX 1989 -42FN	1.73	1.94	2.19	412.96
TGX 1990 -95F	1.60	2.19	2.23	532.47
TGX 1989-45F	1.52	2.43	1.78	167.6
TGX 1990-114FN	1.49	2.18	1.98	491.68
TGX 1989-53FN	1.64	1.72	1.82	273.78
TGX 1993-4FN	1.69.	2.24	2.33	473.29
TGX 1989-75FN	1.63	1.99	1.82	NS**
TGX 1990-78F	1.52	1.94	1.83	NS**
TGX 1967-62F*	1.27	2.13	2.07	586.57
TGX 1448-2E*	1.62	1.58	2.70	429.94
TGX 1989-40F	1.83	2.22	1.98	364.2
TGX 1990-52F	1.49	2.60	2.17	623.4
TGX 1989-48FN	1.80	2.01	2.48	374.1
TGX 1990-40F	1.70	1.64	1.89	NS**
TGX 1989-49FN	1.76	2.56	2.24	616.7
TGX 1990-57F	1.77	2.14	2.43	483.47
TGX 1989-68FN	1.64	2.63.	2.44	462.6
TGX 1990-46F	1.41	1.59	2.47	665.57
TGX 1990-55F	1.41	1.79	2.37	654.61
TGX 1987-10F*	1.14	2.15	2.31	588.52
TGX 1835-10E*	1.25	2.48	1.67	799.94
TGX 1485-1D*	1.65	1.63	1.65	NS**

*= Checks
** Not significant

Picture 1. (a) Mixing of inoculants with soyabean seed for the purpose of assessing the effectiveness on the soyabean performance by Kehinde Tolorunse and Jonathan Madaki, (b) planting of soyabean seed for the purpose of germination and emergence for seed vigour testing by Kehinde Tolorunse and Jame Sunday, and (c) measuring the chlorophyll content using the spad meter for the purpose of determining the greenish of the leaves by Kehinde Tolorunse

enced grain yield, except in TGX 1989-75FN, TGX 1990-78F, TGX 1990-40F and TGX 1485 –1D (Table 1).

Two soyabean genotypes (TGX 1989-45F and TGX 1989-40F) were identified as the overall best in performance in relation to yield and stability. Inoculation of soyabean prove positive, as it enhanced yield across the environments. Inoculated genotypes showed superiority over non-inoculated across the three environments.

Kehinde Tolorunse, Federal University of Technology, Nigeria

Indigenous status of rhizobia in Nigeria: Does this aid its symbiotic performance with cowpea?

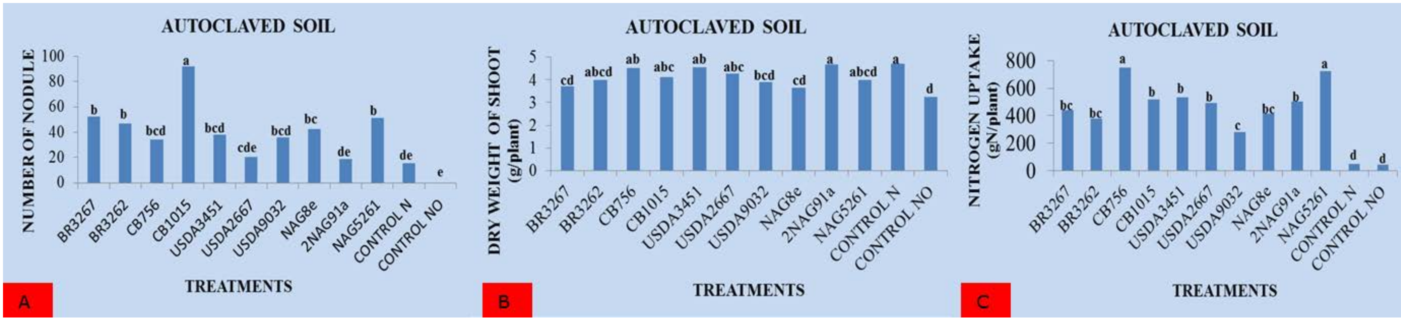
The success of cowpea response to inoculation with effective rhizobia strain in presence of indigenous rhizobia depends on three factors; population density, effectiveness and competitive ability of native African rhizobia. The major aim of my research is to explore the potential benefits of rhizobia inoculation with cowpea in northern Nigeria (Picture 1).

Picture 1. (A) Growing rhizobia strains, (B) Ojo Comfort in the greenhouse with growing cowpea and (C) growth response of cowpea to three different treatments

This study examined the response of cowpea cultivar to inoculation with different rhizobia strains. Cowpea cultivar IT97K-499-35 was inoculated with ten different rhizobia strains and two controls (twelve treatments in total), in soil (autoclaved) collected from field without history of cowpea cultivation and inoculant usage. The history of the soil is indicated in Table 1, showing that the soil contained the appropriate level of rhizobia necessary to nodulate cowpea (100 rhizobia cells gram^{-1} of soil). As shown in Figure 2A, rhizobia strain CB 1015 nodulated cowpea the most, while there was no significant difference in the dry weight of

Table 1. Soil physico-chemical properties and number of rhizobia per gram of soil

Parameters	Soil
pH (H_2O)	5.900
Sand (%)	65.200
Silt (%)	13.200
Clay (%)	21.600
Total N (%)	0.242
Organic carbon (%)	1.898
Available phosphorus (ppm)	1.069
Na (cmol(+) kg^{-1})	0.046
k (cmol(+) kg^{-1})	0.296
Ca (cmol(+) kg^{-1})	5.296
Mg (cmol(+) kg^{-1})	1.401
CEC (cmol(+) kg^{-1})	7.040
Exchangeable acidity (cmol(+) kg^{-1})	0.000
Zn (ppm)	9.926
Cu (ppm)	4.000
Mn (ppm)	124.84
Fe (ppm)	82.745
MPN (Number of rhizobia gram^{-1} of soil)	1.7×10^2



Means followed by equal letters for each measured parameter were not significantly different based on Fisher t-test (P<0.05). 0 = no detection, Control N = without inoculation, but with KNO_3, 0.05%, Control NO = without inoculation and KNO_3, 0.05%

Figure 2. Effect of inoculation of rhizobia strains on cowpea cultivar IT97K-499-35 at eight weeks after inoculation: (A) Number of nodule, (B) dry weight of shoot (g plant^{-1}) and (C) nitrogen uptake (g N plant^{-1})

shoot (Figure 2B) of rhizobia strain 2NAG91a and treatment control N (without inoculation, but with KNO_3). In Figure 2C, rhizobia strains CB756 and NAG5261 fixed the most nitrogen, as compared to the other treatments applied in this experiment. As indicated by the result of shoot dry weight, cowpea showed positive response to inoculation with strain 2NAG91a compared to the treatment with KNO_3 (control N) and without nitrogen source (control NO). These strains (CB756, NAG5261 and 2NAG91a) are all indigenous to African soil. The performance of the Brazilian strain (BR 3262 and BR 3267), known to be highly effective with cowpea, performed less compared to these indigenous African strains. Consequently, there is a need to identify elite strains of cowpea that are indigenous to African soils and develop them as inoculant for cowpea.

Ojo Comfort, Wageningen University, The Netherlands (Click here for her 2015 update)

Assessing the need for rhizobial inoculation of cowpea in Nigeria savannas

Cowpea (*Vigna unguiculata*) is a major staple in Nigeria. Despite this, its yield has remained low at 450 kg ha^{-1} (Omotosho, 2014). Soil infertility, particularly low levels of nitrogen (N), phosphorus and potassium, has been identified as one of the constraints to bridging the yield gap that exists in cowpea production (Mfillige *et al.*, 2014). Grain legumes are normally able to meet part of their nitrogen need through biological nitrogen fixation (BNF). This is however, not always the case, due to the presence of incompatible or ineffective indigenous rhizobial strains in the soil, among other reasons. This limitation can be overcome by the use of elite inoculant strains to improve the input of N from BNF. Furthermore, there is paucity of information on response of cowpea to inoculation in soils of the Nigeria savannas, which account for the major cowpea production in the country. In view of this, a need-to-inoculate experiment was conducted at the greenhouse of the Federal University of Technology, Minna, between October and November 2015 with the following objectives:

- to ascertain if cowpea growth in savanna soils is limited by N;
- to establish if the N-limitation can be overcome by the use of rhizobial inoculant strains.

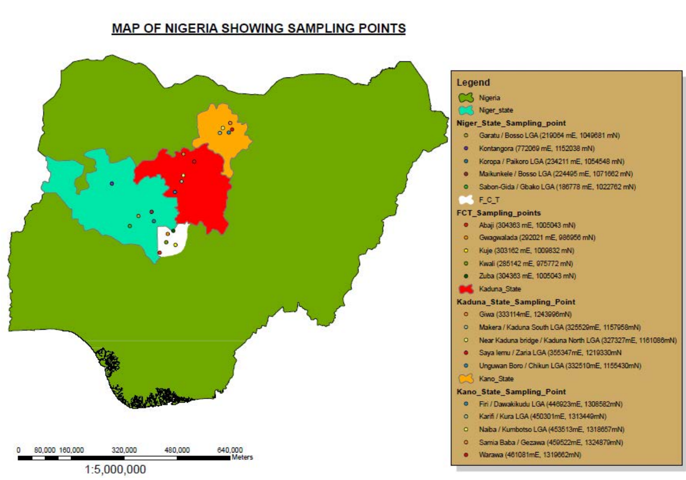


Figure 1. Map of locations in Nigeria Savannas where soil samples were collected

The experiment was a factorial combination of N-sources (Control – devoid of added N or inoculant, inoculant strains and 90 kg N ha^{-1}), two varieties of cowpea and soils collected from 20 locations in Nigeria savanna as shown in Figure 1.

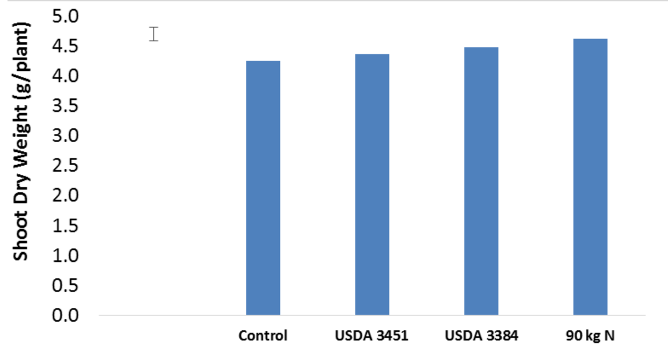
Inoculant strains USDA 3451 and 3384 are of broad spectrum particularly for use in cowpea and groundnut (N2Africa, 2011). All the pots were treated with basal application of essential nutrient element except N, which was applied to only the N-treatments. The experiment was managed in a completely randomized design using three replicates. Plants were harvested seven weeks after planting. Plant shoot dry weight (SDW) were compared as indices of N need of the plants. It is established that N stimulates shoot growth of crop (Moawad and Shamseldin, 2010).

The results showed that the main effects of N-source, variety and location were significant, but not their interactions. The SDW of plants that received 90 kg N ha^{-1} was significantly (P<005) greater than that of the control group, indicating that BNF by the indigenous rhizobia only partially met the N need of the crop (Figure 2).

The inoculant strains increased the SDW of both cowpea varieties over the control plants in 16 out of the 20 locations. The increase however, varied among locations with a range of 3%-70% for USDA 3384 and 3% - 49% for USDA 3451. An increase of at least 15%, which represent an economic threshold (Singleton *et al*., 1990), was obtained in 10 locations for each of the two inoculant strains. Cowpea variety IT99k-573-1-1 had a marginally better response to inoculation than variety IT93K-452-1.

These results suggests that the two elite inoculant strains could establish effective symbiosis with cowpea in soils of the Nigeria savanna. Thus enhancing the yield of cowpea. However, given that the SDW of the inoculated plants were still marginally lower than those of the N-treated plants, a greater number of cowpea inoculants need to be evaluated for cowpea in the Nigeria savanna, which could serve as a cheaper alternative to inorganic N-fertilizer application. In 2016, more inoculant strains will be evaluated for their effectiveness on cowpea in a field experiment.

Adediran Olaotan A., Federal University of Technology, Minna, Nigeria.



I-LSD (P<0.05)

Figure 2. Effect of rhizobial inoculation on shoot dry weight of cowpea

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Exploring options to enhance biological nitrogen fixation and yield of soyabean and common bean in smallholder farming systems in Rwanda

One of my major research activities was a set of trials that evaluated the role of inoculation, P-fertilizer and manure application on common bean and soyabean yield and yield components. As part of this work, I measured nitrogen fixation in both legumes using the ^{15}N-natural abundance method. The proportion of nitrogen derived from atmosphere (%Ndfa) differed between the two legumes

Table 1. Percentage of N derived from atmosphere (Ndfa) and amount of N fixed by common bean as affected by treatments

AEZs / P-fertilizer (kg ha^{-1})	Inoculum	Manure (t ha^{-1})	%Ndfa	Amount of N fixed (kg ha^{-1})
Bugesera				
0	-R	0	26.9	15.54
0	-R	10	13.67	11.97
30	+R	0	26.65	18.54
30	+R	10	27.35	45.39
Kamonyi				
0	-R	0	52.58	59.19
0	-R	10	44.46	73.74
30	+R	0	61.45	82.36
30	+R	10	55.3	138.36
Kayonza				
0	-R	0	42.94	12.76
0	-R	10	11.5	10.17
30	+R	0	32.57	23.78
30	+R	10	32.57	38.72
SED (P-fertilizer x Inoculum x Manure)			**9.27**	**9.45**
SED (AEZs x Manure x Inoculum)			**11.35**	**11.58**
SED (AEZs x P-fertilizer x Inoculum)			**11.35**	**11.58**
SED (AEZs x P-fertilizer x Inoculum x Manure)			**16.06**	**16.37**

Table 2. Percentage of N derived from atmosphere (Ndfa) and amount N fixed (kg ha^{-1}) by soyabean as affected by treatments

AEZs / P-fertilizer (kg ha^{-1})	Inoculum	Manure (t ha^{-1})	%Ndfa	Amount N fixed (kg ha^{-1})
Bugesera				
0	-R	0	45.82	17.50
0	-R	10	27.90	10.45
30	+R	0	39.49	19.87
30	+R	10	27.76	35.26
Kamonyi				
0	-R	0	44.47	49.66
0	-R	10	62.27	129.04
30	+R	0	53.52	82.47
30	+R	10	43.02	130.20
Kayonza				
0	-R	0	69.30	40.92
0	-R	10	21.26	35.06
30	+R	0	31.86	39.43
30	+R	10	24.46	63.53
SED (P-fertilizer x Inoculum x Manure)			12.76	17.20
SED (AEZs x Manure x Inoculum)			15.62	21.06
SED (AEZs x P-fertilizer x Inoculum)			15.62	21.06
SED (AEZs x P-fertilizer x Inoculum x Manure)			22.10	29.79

SED: Standard errors of difference between treatments means
-/+ R: without or with rhizobia (R) inoculation
AEZs: Agro-ecological zones

Picture 1. Soyabean inoculated, with P-fertilizer and manure in Bugesera

Picture 2. Soyabean without inoculation, P-fertilizer and manure in Bugesera

(Table 1 and 2). For both bean and soyabean, the %Ndfa and amount of N_2 fixed were in most cases greater with inoculation, irrespective of manure addition. Application of manure alone led to less %Ndfa, but with a larger amount of N_2 fixed in both legumes. This high amount of N_2 fixed in manured and inoculated treatments is due to good performance of the two legumes resulting in high biomass and good nodulation (Picture 1) recorded at mid-podding compared to control plot (Picture 2). The amount of N_2 fixed also differed between the two legumes and was on average greater in soyabean than in common bean, though the largest value recorded was in common bean (138.36 kg N ha^{-1}). Soyabean produced high biomass in two of the three agro-ecological zones (AEZs), which explained the high amount of N_2 fixed. The amounts of N_2 fixed were also affected by environmental conditions, with highest amount of N_2 fixed observed in AEZ with higher rainfall (Kamonyi).

This study showed that better management leads to substantial amounts of N_2 fixed across the three agro-ecological zones, for both common bean and soyabean. Targeting of legumes to different environmental conditions should consider management as a key driver.

Edouard Rurangwa, Wageningen University, The Netherlands (Click here for his 2015 update)

Maize-grain legume intercropping: Ecological intensification to enhance resource use efficiency and crop productivity for smallholder farmers in northern Ghana

I conducted intercropping trials as key part of my PhD study, for the 2013 and 2014 seasons in the southern (Kpataribogu) and northern (Bundunia) Guinea savanna in northern Ghana. Cowpea, soyabean and groundnut were each intercropped with maize in different planting arrangements. The research objectives were to examine the effects of soil fertility level and different spatial intercropping arrangements (cropping patterns) on maize and legume grain yields, intercrop efficiency and productivity; and to assess the effects of soil fertility level and cropping patterns on N_2-fixation in the two sites. In this update, I present the results of the grain yields of the maize-cowpea system and N_2-fixation by cowpea in 2013. The full paper is currently under preparation.

Cowpea and maize grain yields significantly differed (P<0.001) among cropping patterns, soil fertility level and sites (Figure 1). Grain yields of sole cowpea and maize

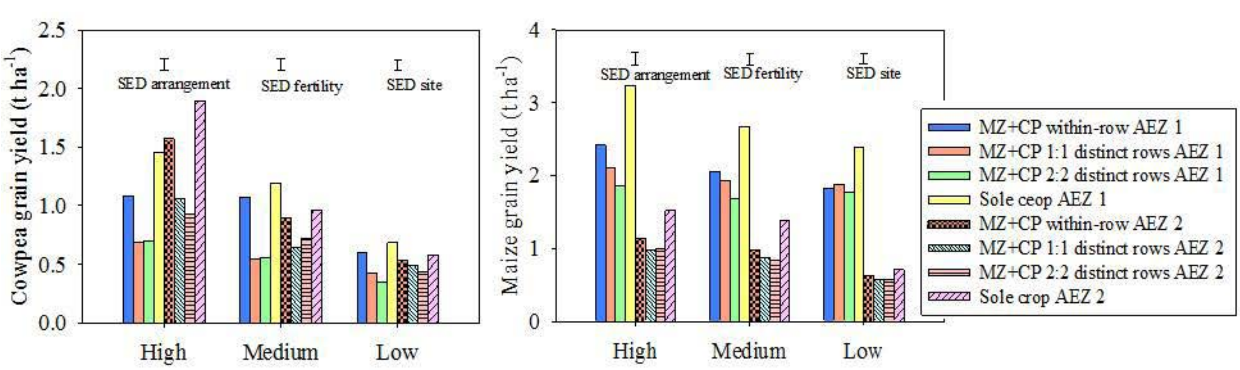


Figure 1. Cowpea and maize grain yields as affected by spatial plant arrangement and soil fertility level in 2013 in Kpataribogu and Bundunia. The error bars show the standard error of difference between means (SED)

were significantly larger, as compared to the intercrop grain yields.

Land size for each intercrop was half the size of land used for each sole crop. Therefore, comparing 50% of each sole crop yield to the respective intercrop yield means comparing equivalent size of land for intercrops and sole crops. The results showed that cowpea and maize intercrop grain yields were significantly higher, as compared with 50% of the sole cowpea and maize yields, respectively. Hence, the results indicated that more land will be required by each sole crop to produce the same grain yield as the intercrops.

The within-row intercrops provided significantly greater grain yield than the 1 to 1 and 2 to 2 distinct row intercrops, both of which did not differ significantly. Cowpea grain yield was significantly larger in Bundunia, while maize grain yield was significantly greater in Kpataribogu. Maize and cowpea grain yields declined with soil fertility level. The high fertility fields significantly (P<0.001) provided larger grain yields than the low fertility fields. The proportion of N derived from N_2-fixation (%Ndfa) generally did not differ between intercrop and sole crop (Table 1). However, the sole cowpea yielded significantly higher amount of N_2-fixed than the intercrops, due to larger amount of above ground biomass produced. The low fertility field mostly provided a significantly larger %Ndfa than the high fertility field, but only at Bundunia. However, the amount of N_2 fixed was significantly larger (P<0.001) in the high fertility field than the low fertility field due to larger amount of above ground biomass produced. The %Ndfa and amount of N_2 fixed were significantly (P<0.001) larger at Bundunia, as compared to Kpataribogu.

Table 1. Proportion of N derived from N_2-fixation (%Ndfa) and N_2-fixed (kg ha^{-1}) by cowpea as affected by cropping pattern and soil fertility level in Kpataribogu and Bundunia

	High fertility		Low fertility		High fertility		Low fertility	
Cropping pattern	% Ndfa	N_2-fixed	% Ndfa	N_2-fixed	% Ndfa	N_2-fixed	% Ndfa	N_2-fixed
	Kpataribogu				*Bundunia*			
Intercrop	22	10.8	53	12.5	62	29.1	80	10.8
Sole cowpea	28	21.0	54	11.8	62	36.9	85	14.1
Mean	25	15.9	54	12.1	62	33.0	83	12.5

The results showed that intercropping improved the efficiency and productivity of the prevailing land to provide food. The within-row intercrop pattern seemed to be the more efficient and productive system. The distinct row intercrop patterns were also beneficial, as compared to sole crops. Low soil fertility enhanced the proportion of N derived from N_2-fixation. However, good soil fertility is required for increased biomass production and ultimately higher amount of N_2 fixed.

Michael Kermah, Wageningen University, The Netherlands (Click here for his 2015 update)

Abundance and morphological characteristics of rhizobia nodulating common bean in Uganda

We used the plant infection technique to estimate the population of rhizobia in soils obtained from the Montane and Mt. Elgon agro-ecological zones (AEZs), focusing on three land use management practices across an elevation gradient. There were larger numbers of bean-nodulating bacteria (shown by the MPN range) in cultivated land as compared to forest and grassland (Table 1).

Table 1. MPN estimation using the plant infection technique from soils obtained from the Montane and Mt. Elgon agro-ecological zones

Land Use	Number of samples	MPN Range
Cultivated land	32	3.1×10^1 - 1.7×10^4
Forest land	14	0.0 - 1.4×10^4
Grassland	13	0.0 - 5.8×10^3

With a minimum of 20 isolates per soil sample, 500 isolations were made from bean nodules. The following colony morphologies were observed; white, opaque and raised (70%) and white, translucent and raised (30%) with a colony diameter ranging from 1.0-2.0 mm after 2-3 days. Less than 10 colonies had a colony diameter ranging from 3.0-4.0 mm. The isolates were stored in a broth-glycerol mixture for further work and also used in subsequent authentication experiments.

From the authentication experiments under sterile conditions in a growth chamber for 133 isolates, 244 out of 266 duplicate runs generated a positive authentication giving a nodulation efficiency of 91.7%. Future work will involve DNA sequencing and effectiveness tests of the isolates in comparison with commercial inoculants.

Figure 1. (a) Isolation of rhizobia on YEMA-CR media and (b) sterile nutrient solution addition during authentication tests of the isolates in a growth chamber

Allan Ochieng, Wageningen University, The Netherlands (Click here for his 2015 update)

Grain legume residues: Livestock fatteners' most vital feed resource in northern Ghana

Livestock fattening is one of the major occupations of the people of Bawku in the Upper East Region of Ghana. It is a business considered to be for landless people in the society. Bawku is one of the project districts of the N2Africa project. The district is highly populated and farming land is a scarce commodity.

As part of my PhD work, I am assessing the trends in the use and management of grain legume residues (GLRs) among different farm types and other livestock production chain actors in northern Ghana. Based on this, focus group discussions (FGDs) were held with groups of smallholder farmers, livestock traders and fatteners.

Focus group discussion held with Kpolore Livestock Farmers Association (mainly fatteners) in Bawku revealed how important N2Africa Project is to their business. They stated that any innovation and technology improving the productivity of grain legumes is a booster to their enterprises, because they make GLRs available and easily accessible. The core business of these livestock fatteners is to fatten animals, particularly ruminants (cattle, sheep and goats), for special occasions such as Christian and Moslem festivals in Ghana. These livestock fatteners obtain their animals from smallholder farmers at local markets around Bawku in Ghana and from other villages along the borders of Burkina Faso and Togo. They keep their animals for a particular period of time under intensive management system, where the animals are fed indoor. During the keeping period, the animals are fed, watered, dewormed and treated against any ill-health issues to attain a accepted size and weight for the market.

Preliminary results from the study indicated that about 70% of the feed resources for fattening livestock are composed of GLRs (particularly cowpea, groundnut and soyabean residues). Cereal residues from crops, such as maize, rice sorghum and millet, provided about 20% of their feed and the remaining 10% came from other sources. Among the GLRs, cowpea haulms were rated as the most nutritious feed, followed by groundnut and soyabean, being the least rated among the three main grain legumes grown in northern Ghana. The rating was based on the following criteria; acceptance among animals, number of leaves on the stocks, storability and fibrous nature of the stocks. Another important finding worth noting is the fact that market has been created for GLRs (Figure 1). This market employs many people, especially women in selling GLRs to earn additional income. We visited the farm of Mr Abdala Awal and he told us he is making a living as a livestock fattener, because he is able to cater for his family, pay his children's school fees and save for future businesses (Figure 2).

Figure 2. Mr Abdala Awal with some of his fattened animals ready for the market

However, these fatteners face challenges, such as high cost of veterinary medicines and services, high cost of formulated feeds (concentrates) and shortage of water during the dry season. They also complained about lack of financial services to support their business.

Detailed studies will be conducted to investigate the trends in the use and management of GLRs among livestock production chain actors and also to quantify the return on investment of livestock fatteners as compared to smallholder farmers and livestock traders.

Daniel Brain Akakpo, Wageningen University, The Netherlands (Click here for his 2015 update)

Figure 1. Grain legume residues being conveyed to the market for sale in Bawku, Ghana

Nutritional benefits of improved grain legume cultivation in Ghana and Kenya

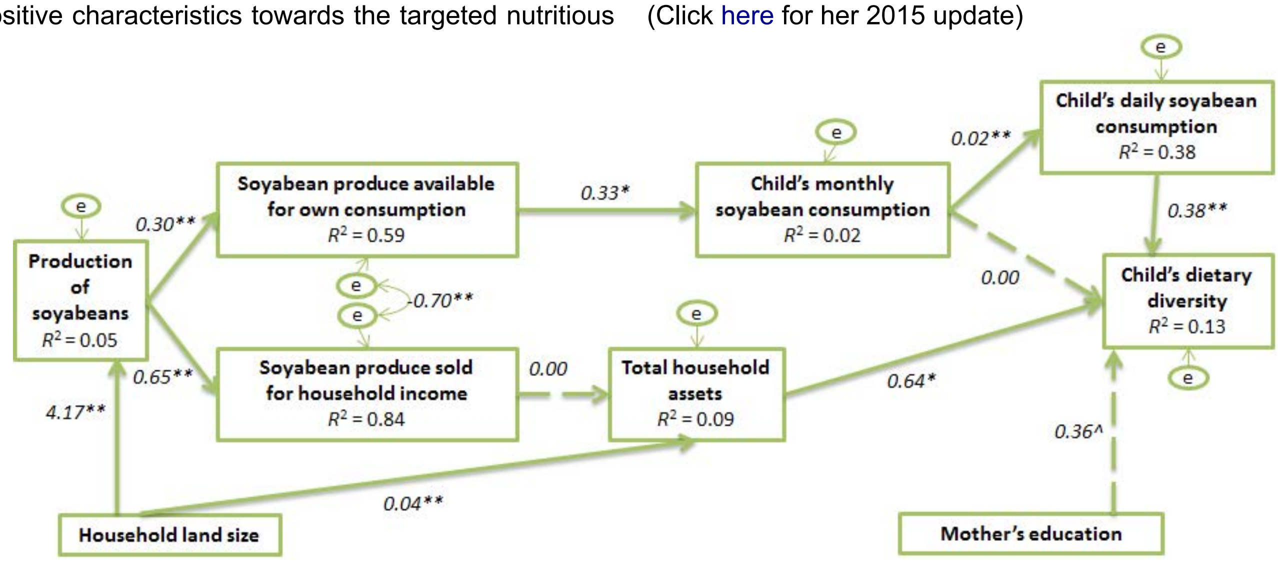
In contrast to my first PhD period within the N2Africa project, last year I spent most of my time behind my desk analysing data, discussing results with others and writing. I hope to soon share with you my first paper *'Child's nutritional benefits of improved grain legume cultivation in smallholder farming households in rural Ghana and Kenya'*.

As shared earlier, we found no association between N2Africa and nutritional outcomes (legume consumption and individual dietary diversity) of Ghanaian and Kenyan infants and young children. Although overall grain legumes (especially soyabean) were cultivated by a greater fraction of the N2Africa households in both Ghana and Kenya, the total household production of grain legumes did not differ between the N2Africa and non-N2Africa households. As improved nutrition outcomes by N2Africa depend on the level of total household legume production, we combined the data from the non-N2Africa group and the N2Africa group and further explored the production-own consumption and income-food purchase pathway for soyabean in Ghana and Kenya. In Kenya but not in Ghana, we observed a positive effect of soyabean production on child's dietary diversity through the production-own consumption pathway (Figure 1). The different findings in Ghana and Kenya suggest the importance of context characteristics. The study shows that a context where (a) farmers attribute positive characteristics towards the targeted nutritious food, (b) a wide variety of local dishes already include the promoted food, (c) women are involved, (d) the targeted nutritious food is a new crop and a food crop, a project like N2Africa has more potential to indirectly improve child's dietary diversity through the production-own consumption pathway. In Ghana and Kenya, we found no effect through the income-food purchase pathway.

Currently, I am analysing whether household food production supports household and child's nutrition needs and food-based dietary guidelines in northern Ghana. Household production used for own consumption has the potential to cover the macronutrient (except fat), but not the micronutrient needs. Existing nutrient and food gaps may give direction to which crops need further production investment or improved market availability for affordable prices.

Last June, I attended the Agriculture Nutrition and Health Academy (ANH) Week in Addis Ababa, Ethiopia. This week included interesting relevant practical workshops and I talked with many researchers working on agriculture and food systems for improved nutrition and health. It was great to share my own research results with others and place them in a wider context.

Ilse de Jager, Wageningen University, The Netherlands
(Click here for her 2015 update)



Values are unstandardized regression coefficients (^*P*<0.10, **P*<0.05, ***P*<0.01, path coefficients not significantly different from zero are shown by broken lines). Value between error terms of soyabean yield available for own consumption and for household income is the estimated correlation. Part of the variance explained by the model (R_2) is given under the variable names.

Figure 1. Explorative structural equation model of the effect of soyabean production on dietary diversity of children 6-59 months through production-own consumption pathway and income-food purchase pathway in rural western Kenya (n=197)

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