N2Africa Podcaster no. 47
PhD Student Special

August and September 2017

Introduction

Welcome to this special N2Africa PhD Update. Each year around this time we ask all of the PhD candidates either directly funded by N2Africa or affiliated to the project to provide an update on the status of their work. As you will see it is a rich harvest! Two candidates Amaral Chibebe (Mozambique) and George Mwenda (Kenya) have already completed their PhDs. Amaral is back in Mozambique working as a rhizobiologist for IITA. We extend our congratulations to George who just graduated on the 14th September. He is still in Australia working part-time as a teaching assistant for biochemistry and cell biology laboratory sessions for undergraduates at Murdoch University. At the same time he is busy writing papers from his thesis and applying for post-doc positions – so if you know of any vacancies please let him know! Several other PhD candidates have published journal articles already and are well on their way to completing their degrees, whereas others are still in the major phase of field work and experimentation. A few have just started as their studies will focus on evaluation of the dissemination methods used in N2Africa as part of the overall impact studies.

We are particularly proud of the wide range of topics covered by the PhDs. They are covering everything from molecular characterisation of the rhizobia nodulating the key legumes, the legume genotype by rhizobial genotype interaction, field measurements of nitrogen fixation and crop performance, the role of legume crop residues in animal production, participatory studies of farmers' adaptation of N2Africa technologies, farm scale modelling and marketing studies of public-private partnerships. This reflects the interdisciplinary nature of N2Africa and the range of disciplines needed to fill the legume-rhizobium technology pipeline from discovery to application to address the needs of African smallholders.

Left to right: Dr Jason Terpolilli (PhD supervisor), Dr George Mwenda, Dr Amanuel Asrat (fellow graduand) and Dr Graham O'Hara (PhD supervisor)

As N2Africa is now producing a lot of research outputs in the form of journal articles I highlight two things: First, all of our papers must be published in "Open Access" journals and The Bill & Melinda Gates Foundation will cover publication costs. Please contact us to see how to arrange this. Second, please only submit your papers to reputable journals – we are happy to advise on which journals we should choose and which to avoid. Predatory journals are increasingly trapping even experienced researchers (see this link) – so many of these journals have no proper editorial process and are not 'peer reviewed'. it is a real pity if good research gets tainted in this way.

Read on! We look forward to hearing your feedback and suggestions, and to receiving your news and updates from the field for the next Podcaster.

Ken Giller

Introducing Travis Goron

I recently completed my PhD at the University of Guelph in Canada, specializing in crop plant physiology, specifically nitrogen metabolism in maize. My previous research group also conducted work concerning smallholder cropping systems in Nepal, which captured my interest – I was able to conduct a couple of side experiments with finger millet, a very important Nepali crop.

Earlier this year, I was lucky enough to be awarded an NSERC Postdoctoral Fellowship from the Canadian government to come work with N2Africa for 2 years. I'll be conducting a focused study of the non-nitrogen benefits which occur when rotating cereals with legumes in Sub-Saharan Africa. These benefits can include pest and weed reduction, soil improvements, and many other interesting effects. Most importantly, I'm looking forward to meeting as many of you as possible

Travis harvesting a finger millet plant for root analysis in Canada

Travis Goron, Wageningen University and Research

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

Field trials were conducted in 2015 and 2016 seasons to evaluate the response of groundnut (*Arachis hypogaea* L.) varieties (KAMPALA, KWANKWASO, SAMNUT 21, SAMNUT 23, SAMNUT 24, and SAMNUT 25) to rhizobial inoculation treatments (rhizobium strains NC 92, SBG 234, MJR 518, WDL 129, +N (20 kg N ha^{-1}), and -N (Control)) in the Sudan and northern Guinea savannas of Nigeria. Results of the 2015 trials were reported in Podcaster 39. The results obtained in 2016 showed similar trends to 2015. Analysis of the two seasons data showed that none of the inoculation treatments had significant ($p \leq 0.01$) effects with respect to all variables measured[1] except shoot dry weight per plant in both locations, haulm yield per ha in Sudan savanna (SS) in 2015, and number of nodules per plant in both locations in 2016. However, the varieties significantly differed ($p \leq 0.01$) in all variables measured except nodule dry weight per plant and root dry weight per plant in northern Guinea savanna (NGS) in 2015, and number of nodules per plant in both locations in 2016. The interaction between variety and rhizobia inoculation was only significant on haulm yield per ha in SS in 2015 (Figure 1) and nodule dry weight per plant in NGS in 2016 (Figure 2). SAMNUT 24 was the best variety across locations and in both seasons even though there was no significant relation between inoculation and yield. However, SBG 234 and WDL 129 showed some potential of being selected as inoculant based on the shoot dry weight results from 2015 and the number of nodules per plant in 2016. Furthermore, the result of the interaction (Figure 2) also indicated high performance of the strains.

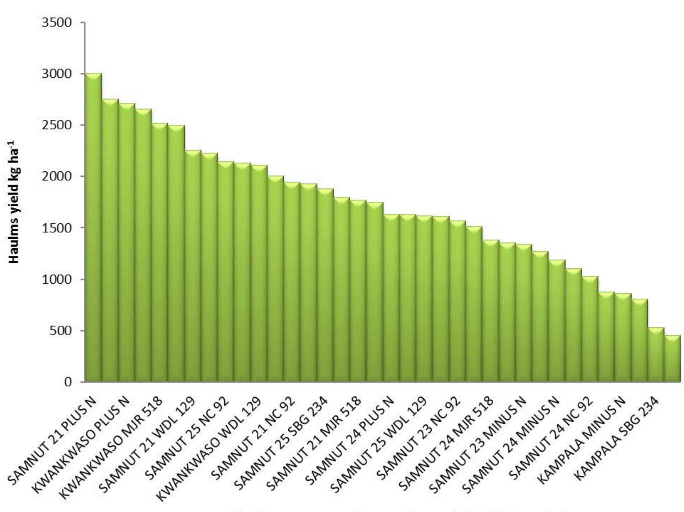

Figure 1: Interaction effect of groundnut variety and rhizobia inoculation on haulm yield

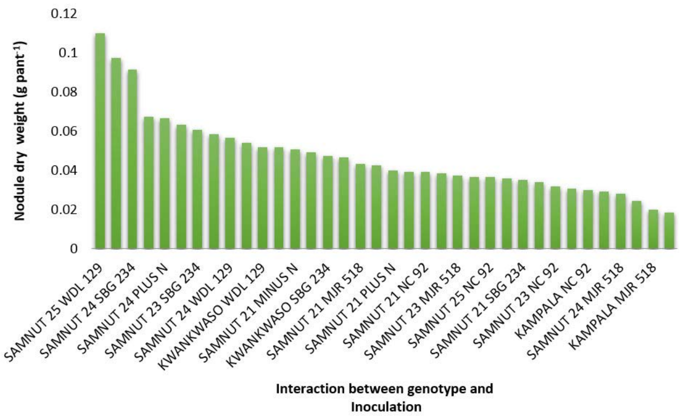

Figure 2: Interaction effect of groundnut variety and rhizobia inoculation on nodule dry weight

The field work is completed and laboratory analyses on soil and plant samples are in progress to determine biological nitrogen fixation potentials and soil N balance with respect to the varieties used in the study. Meanwhile, a paper has been submitted for presentation at Crop Science Society of Nigeria (CSSN) Conference for sharing the information of the research with fellow scientists for further collaboration in the field of Rhizobiology. Furthermore, I have started writing my thesis and seminar papers from the results obtained so far.

Faruk Galadanchi Umar, Bayero University, Nigeria (Click here for his 2016 update)

[1]chlorophyll content; number of nodules per plant; nodule dry weight per plant; root dry weight per plant; shoot dry weight per plant; pod yield per ha; kernel yield per ha; shelling percentage; hundred seed weight; haulm yield per ha; and harvest index

Assessment of the impact of improved cowpea varieties on women farmers in southern part of Borno State, Nigeria

I study the impact of improved cowpea varieties on women farmers in the Southern Part of Borno State, Nigeria. These technologies were introduced by the *Promoting Sustainable Agriculture in Borno State*, (PROSAB) project which was operative from 2004 to 2009. The specific objectives of this study were to identify the changes in income of women farmers as a result of using improved cowpea varieties, to analyse the impact of the improved technology on the food security status of women farmers and to identify constraints associated with the use of improved cowpea varieties.

Primary data were collected by means of structured questionnaires administered to 240 randomly-selected women farmers who participated in the PROSAB project and also planted the improved cowpea introduced (participants) and 60 farmers who did not participate (non-participants), giving a total of 300 respondents. Secondary data used came from a baseline survey conducted when the PROSAB project was implemented in 2004. The double difference (DD), the cost-of-calorie index and descriptive statistics were used to analyze all data. The DD is the difference between the income of both the participants and non-participants before implementation of the PROSAB project (2004) and after the project had ended (the project ended in 2009 and this study was conducted in 2015).

The results showed that the use of improved cowpea varieties had a positive impact on income (Table 1). The annual income of the participants increased by ₦143,495 ($725), whereas the income of non-participants increased by only ₦58,500 ($295). The increase in the income of non-participants was a result of a spill-over effect from those who adopted the improved cowpea technology.

The food insecurity line, Z – the costs of acquiring minimum energy requirements of 2260 Kcal per adult equivalent (FAO, 2009) – was determined at ₦1,975 per month before PROSAB. This rendered 58% of the households food insecure and 42% food secure. The deficit in aggregate income of food-insecure households was ₦376 (Table 2). For participants, the food insecurity line was determined at ₦2,744 per month after PROSAB. Of the participants, 34% was food insecure and 66% was food secure. This implies that food insecurity among the participants could have been reduced as a result of the PROSAB intervention. An extra ₦412 was required by food insecure participants to become food secure. The food insecurity line of non-participants was ₦2,077 per month after PROSAB. Two-thirds of them were food insecure and required an additional ₦784 to meet their basic food needs. The DD indicated a positive difference of ₦667 in the food security line of participants compared to non-participants. This shows that the improved cowpea technology had a positive impact on the food security of the respondents.

Table 3. Constraints faced by women farmers regarding the production of improved cowpea production

	Participants		Non-participants	
Constraint	Frequency	Percentage (%)	Frequency	Percentage (%)
Inadequate Seed supply	29	12	54	90
High cost of seeds	17	7	46	76
Inadequate access to market	60	25	52	87
Inadequate extension visits	38	16	56	93
Inadequate fertilizer	24	10	41	68
Tenure problem	38	16	7	12
High cost of labour	84	35	8	13
Diseases and pests	209	87	59	98
Low yield	34	14	46	76
Drought	31	13	39	65
Inadequate information on improved seed	5	2	58	97

Source: Computed from Field Survey Data, 2015

The women cowpea farmers were constrained by various factors like diseases and pests, high costs of labour, lack of seeds of the new varieties, inadequate information and inadequate access to markets (Table 3).

Table 1: Average household income from cowpea before (2004) and after (2015) the PROSAB project.
(*** : significant at 1%).

	Income from cowpea before PROSAB (₦)	Income from cowpea after PROSAB (₦)	Income difference (₦)	Double Difference (%)	Double Difference (DD) (₦)	T-Value
Participants	56,005	199,500	143,495	256	84,995	8.43***
Non-Participants	31,000	89,500	58,500	189		

Table 2: Food security among women in Southern Borno State. T-values between parentheses.

	Before PROSAB	After PROSAB		
		Participants	Non-Participants	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)	
Daily energy requirement (Kcal)	2260	2260	2260	
Food insecurity line (Z) per month (₦)	1,975	2,744	2,077	668
Percentage Food Insecure	58%	34%	67%	-33%
Percentage Food Secure	42%	66%	33%	33%
Income deficit preventing food security (₦)	376	412	784	371

It is recommended to formulate policies that encourage women farmers in the study area to adopt and sustain the use of improved varieties of cowpea. 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. The women farmers in the study area should be given adequate information on how to control pests and diseases. The women farmers' access to extension services and their number of contacts with extension agents should be increased especially for the non-participants.

Binta Ali Zongoma, Department of Agricultrual Economics, University of Maiduguri, Nigeria (Click here for her 2016 update)

Yield stability studies on soyabean genotypes under Rhizobia inoculation in the Savanna Region of Nigeria

Soyabean (*Glycine max* L.) is the world's important food legume of great nutritional value. The crop has the highest protein content (40%) of all food crops and is equivalent to proteins of animal products. The crop holds considerable potential for arresting soil fertility decline and enhancing household food nutrition. Therefore, this study aimed at exploiting soyabean genotypes for yield under Rhizobia inoculation across three locations in the Savanna Region of Nigeria.

Methodology

In this study, 24 soyabean genotypes including five commercial checks were evaluated across three different agro-ecological zones in Northern Nigeria. These environments differed in terms of soil pH, nitrogen, available phosphorus and potassium. The inoculants LegumeFix and NoduMax were used in each location. Inoculation was assessed at three levels; without inoculation, with Legumefix and with Nodumax. This therefore resulted in 72 (24 x 3) treatment combinations. A split-plot design with three replications per treatment was adopted at each location, resulting in a total of 216 (72 × 3) sub-plots. The main plots consisted of the soyabean lines and the sub-plots were the inoculant applications.

Figure 1. (Left) Planting of soyabean seed for the purpose of germination and emergence for seed vigour testing by Kehinde Tolorunse. (Right) Data collection on the field by Kehinde Tolorunse and Sunday Joshua

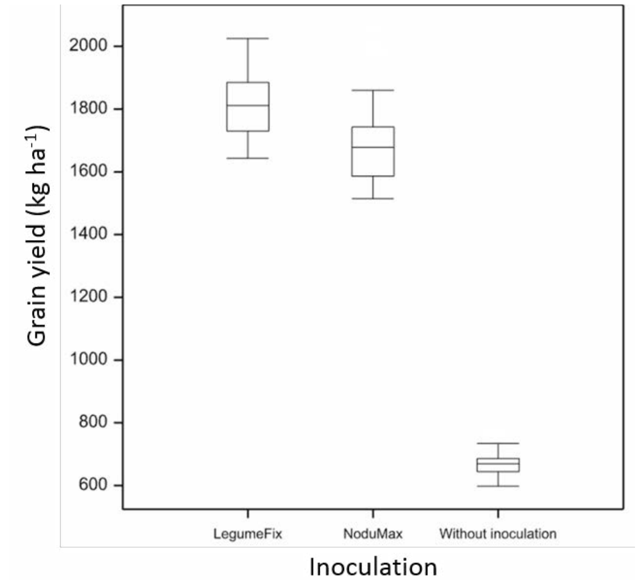

Figure 2: Boxplot for grain yield (kg ha^{-1}) from soyabean genotype inoculation

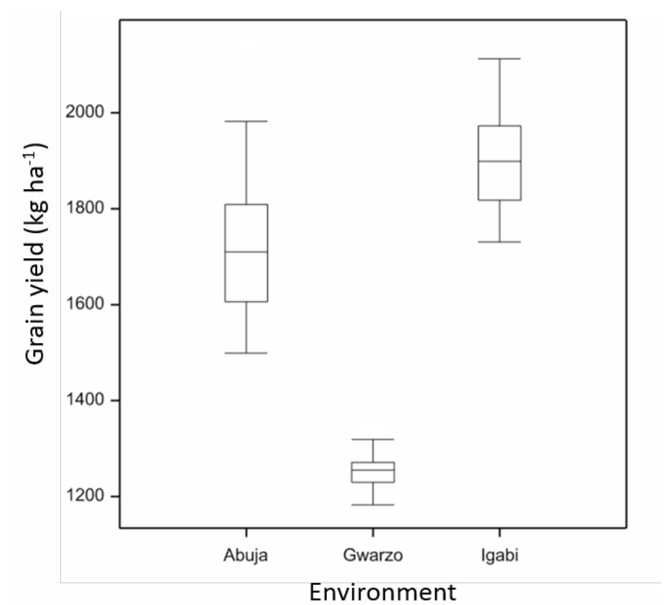

Figure 3: Boxplot for grain yield (kg ha^{-1}) across environments

Results

There were significant differences in emergence percentage, number of leaves, height, chlorophyll content, branches per plant, pods per plant were observed except days to 50% flowering, for the different inoculation treatments. Inoculation significantly influenced grain yield and LegumeFix inoculation treatment recorded the best mean performance, followed by NoduMax as revealed in Figure 2.

Soyabean grain yields for the 24 genotypes were significantly different (P=0.05) across the locations, with higher yields in the Igabi environment compared to Abuja and Gwarzo environments (Figure 3).

Conclusion

For large scale production, environments like Igabi and Abuja should be considered in order to ensure high yield, effective production and food security. Inoculation of soyabean proved positive as it enhanced yields across the environments. Inoculated genotypes showed superiority in terms of yield over non-inoculated across the three environments.

These results from 2016 confirmed the observations from the experiments performed in 2015 on the same locations and with the same treatments.

Kehinde Tolorunse, Federal University of Technology, Minna, Nigeria (Click here for his 2016 update)

The effects of inoculation, P application and sequential cropping on cowpea varieties on farmer's fields in Minna, southern Guinea savanna of Nigeria

Two field trials were conducted in the 2016 cropping season. The first was conducted to determine the effect of phosphorus fertilizer application and rhizobial inoculation on nodulation, N_2-fixation, growth and productivity of three cowpea varieties on three farmer's fields in Minna, in the southern guinea savanna of Nigeria.

The treatments of the first trial were combinations of the following three components: (1) either inoculation with BR 3262 or BR 3267 strain, or the application of 90 kg N/ha, (2) phosphorus fertilizer application at one out of three rates (0, 20 and 40 P kg/ha), and (3) one out of three cowpea varieties (IT99k-573-1-1, IT93K-452-1 and TVX 3236). The control was uninoculated and unfertilized with N. It was a factorial experiment arranged in a randomized complete block design. Each farmer's field served as a replicate. Data on growth, nodulation, N_2-fixation, biomass production and grain yield were collected.

The results revealed that:

- Phosphorus fertilizer application increased the growth, nodulation, N_2-fixation and yield of the three cowpea varieties used. Plants without P-fertilizer consistently gave the lowest values in all the parameters measured and the values obtained in plants that received 20 and 40 kg P/ha were at par for many of the parameters measured (Fig 1);
- Variety IT99k-573-1-1 recorded a marginally higher biomass and grain yield than the other two varieties;
- There was no significant difference between the inoculated and control plants with respect to nodulation, biomass and grain yield. Plants that received 90 kg N/ha had marginally higher biomass and grain yield than the inoculated and control plants (Figure 2);
- In general, there were no significant interactions between the applied treatments.

The second experiment was conducted to evaluate the performance of six varieties of cowpea (IT93K-452-1, IT90K-76, Oloyin, IT99K-573-1-1, TVX-3236 and Kanannado) in a cowpea-cowpea sequential cropping system on three farmers' fields in Minna, southern guinea savanna of Nigeria. Each farmer's field served as a replicate. The aim was to identify the varieties that can be grown more than once within a season and also produce high yield in a bid to intensify the production of the crop. The first planting was done in mid-May and the second planting was done immediately after the harvest of the first crop on the same plot. Data were collected on growth, yield and economic profitability of the productivity.

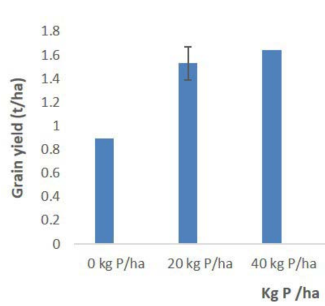

Figure 1. Grain yield of cowpea as affected by phosphorus application

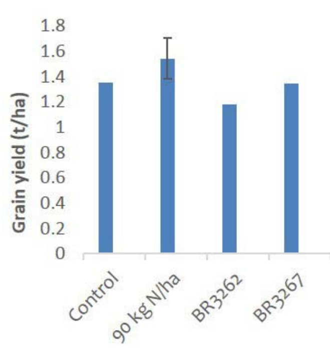

Figure 2. Grain yield of cowpea as affected by rhizobial inoculation

The student collecting data on the field

The results revealed that:

- All the varieties were successfully planted twice in a season except Kanannado which was planted only once because it was photoperiod sensitive and late maturing (Figure 3);
- Of the five varieties that were planted twice, IT99k-573-1-1 had the highest cumulative yield (3.01 t/ha) followed by IT90K-76 (2.7 t/ha). Oloyin yielded the least (0.65 t/ha) (Figure 4);

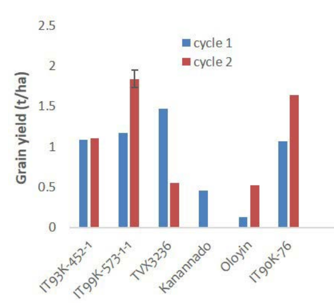

Figure 3. Grain yield of cowpea varieties planted in sequence

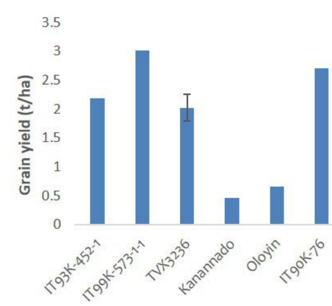

Figure 4. Cummulative yield of cowpea varieties planted in sequence

- Cultivation of IT99k-573-1-1 twice in a season is most profitable to farmers: it has a cost-benefit ratio of 2.38 and a gross margin (GM) of N 1,009,000 ($2,802) per year compared to the ratio of 2.21 and GM of N 592,500 ($1,646) that is obtainable if the farmer plants once in a season;
- If the farmer was to pay for all the inputs and labour on the farm, the farmer will produce Oloyin and Kanannado varieties at a loss. This shows the importance of the need to use improved varieties by farmers.

Conclusions

The results of these experiments show that:

1. The application of 20 kg P/ha is adequate for the optimum performance of cowpea varieties IT99k-573-1-1, IT93K-452-1 and TVX 3236 in the study area;
2. The symbiotic effectiveness of the rhizobial inoculants used was not better than the indigenous strain present in the soil in Minna;
3. Variety IT99K-573-1-1 could be nominated as the best cowpea variety for optimum yield and profitability;
4. Varieties IT99K-573-1-1, IT90K-76, IT93K-452-1 and TVX 3236 (listed in the order of performance with regard cumulative yield) can be recommended for cultivation in a cowpea-cowpea sequential cropping system.

Adediran Olaotan Abimbola. Federal University of Technology, Minna, Nigeria (Click here for her 2016 update)

Percentage similarity of indigenous rhizobia across different agro ecological zones in Nigeria

Legumes are capable of establishing symbiotic associations with rhizobia in a process called biological nitrogen fixation which is responsible for the wide adoption of legumes as food crops, forages, green manures and in forestry. Recently, the call for the return to a sustainable form of agriculture due to pollution of water body by nitrate and increase in cost fertilizer has caused an increased interest in biological N_2-fixation. Therefore, usage of N_2-fixing legumes is not limited to only cash crop or biofuel but could be important in the recovery and improvement of soil fertility. Therefore it is timely to obtain new information regarding legumes and diazotrophic symbiotic bacteria. The process leading to the identification of effective rhizobia strains for cowpea could be labour and time consuming and often result into production of several rhizobia cultures. Therefore, it is imperative we charactize them genetically. This study was carried out to test the discriminatory power and reproducibility of BOX-PCR for fingerprinting rhizobia.

Rhizobia strains were diluted in sterile water and amplified by PCR with primer BOX A1R (5′-CTACGGCAAGGCG ACGCTGACG-3′). These strains included isolated indigenous strains. The amplified fragments were separated by horizontal electrophoresis on 2% agarose gel, stained with ethidium bromide, visualized under UV radiation and photographed. The sizes of the fragments were normalized according to the sizes of the DNA markers. Cluster analyses of the BOX-PCR profiles were performed using GelJ program (version 1.0) with the UPGMA algorithm and the Jaccard coefficient, considering the optimum values indicated by the GelJ program for the tolerance and optimization parameters.

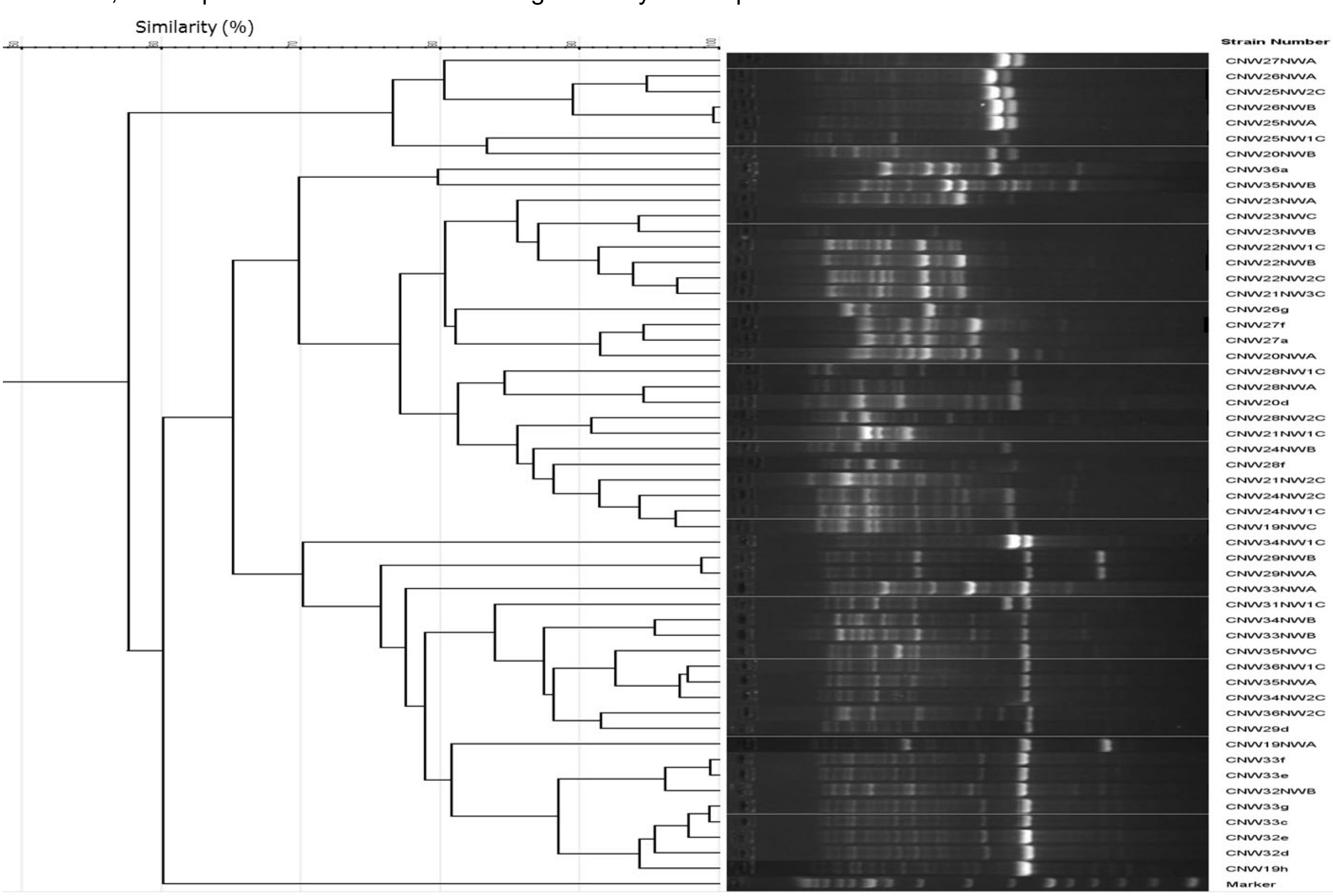

Figure 1. Similarity percentage among strains isolated from nodules trapped from soil collected from Kaduna agro ecological zone

Well defined groups with a high level of inter and intra specific diversity and complex fingerprinting patterns with multiple distinct bands of various intensities were obtained in the BOX-PCR analysis of the rhizobia strains from the different agroecological zones (Figure 1). Images for Niger and Kano Agro ecological zones not shown). None of the strains showed identical (100% similarity) fingerprints, but 99% of similarity or higher were obtained for strains CNW26NWB & CNW25NWA (99.3%), CNW33f & CNW33e (99%)-Kaduna and CNW49NW1C & CNW49NW2C (99.1%)-Kano. In the cluster analysis of the BOX-PCR profiles, strains from each agroecological zone were grouped at similarity levels; Niger 60% (15 groups), Kaduna 58% (37 groups) shown in figure 1, Kano 57% (43 groups).

Consensus sequences such as BOX related to repetitive and conservative elements diffused in DNA have been extensively used in ecology, genetic and taxonomic studies as well as for rhizobia strain identification and the technique has also proven to be valuable in studies of rhizobia isolated from tropical soils. As shown from the result, other than detection of genetic diversity, the BOX fingerprinting tool was able to show the percentage level of similarity among the different strains from each agro ecological zones. This obtained information might be important when considering the same set of rhizobia strains for phylogenetic analysis of the 16SrRNA region in their genome. Also there will be need to test the effectiveness of these strains in the greenhouse so as to decipher the pattern of N_2-fixation with their host cowpea.

Comfort Ojo Tinuade, Wageningen University & Research, The Netherlands (Click here for her 2016 update)

How do climbing beans fit in farming systems of the eastern highlands of Uganda? Opportunities and trade-offs at farm level

Climbing beans are a new crop for farmers in Kapchorwa district, on the northern slopes of Mt Elgon in Uganda. I assessed the effects of the introduction and expansion of climbing bean cultivation at the farm level: what contribution do climbing bean have to food self-sufficiency and income, and what are trade-offs in terms of investment costs and labour. Based on a farm typology and detailed farm characterization (DFC) (Marinus, 2015), we explored the effects of four different options for climbing bean cultivation: *Option 1*: climbing bean intercropping (CBI) with banana/ coffee; *Option 2*: climbing bean with maize stalks (CBMS) – relay cropping whereby maize cobs are harvested and stalks are left in the field to serve as stakes; *Option 3*: climbing beans replace maize (CBRM) – 50% of a maize + bush bean field is replaced with a sole crop of climbing bean; Option 4: climbing bean sole cropping (CBS) with wooden stakes.

Most households participating in the DFC were food self-sufficient in their current situation (Figure 1). Food self-sufficiency was increased with climbing beans in all options, with the exception of option 3: maize yields more in kg of produce and caloric value, so replacing 50% of maize + bush bean with climbing bean was not beneficial for food self-sufficiency. Option 4 provided the largest increase. As prices for climbing bean were better than for maize, the income gained from option 3 was larger than obtained from maize + bush bean cultivation (Table 1). The other options were compared with bush bean cultivation, as climbing beans would often replace these crops when introduced on the farm. Income increased compared with bush bean cultivation. However, investment costs were also

Table 1. Average income, cost and profit (USD ha^{-1}); income : cost ratio and returns to labour (USD day^{-1}) per option and in comparison with bush bean or maize + bush bean cultivation

	Income (USD ha^{-1})	Cost (USD ha^{-1})	Profit (USD ha^{-1})	Income : cost ratio	Returns to labour (USD day^{-1})
Option 1 (CBI)	558	267	291	2.1	0.9
Bush bean intercropping	*279*	*53*	*226*	*5.2*	*0.5*
Option 2 (CBMS)	868	52	815	16.6	1.8
Bush bean sole cropping	*458*	*53*	*404*	*8.6*	*2.1*
Option 3 (CBRM)	1300	321	979	4.1	3.2
Maize + bush bean	*888*	*278*	*610*	*3.2*	*4.1*
Option 4 (CBS)	1336	282	1055	4.8	2.2
Bush bean sole cropping	*458*	*53*	*404*	*8.6*	*2.1*

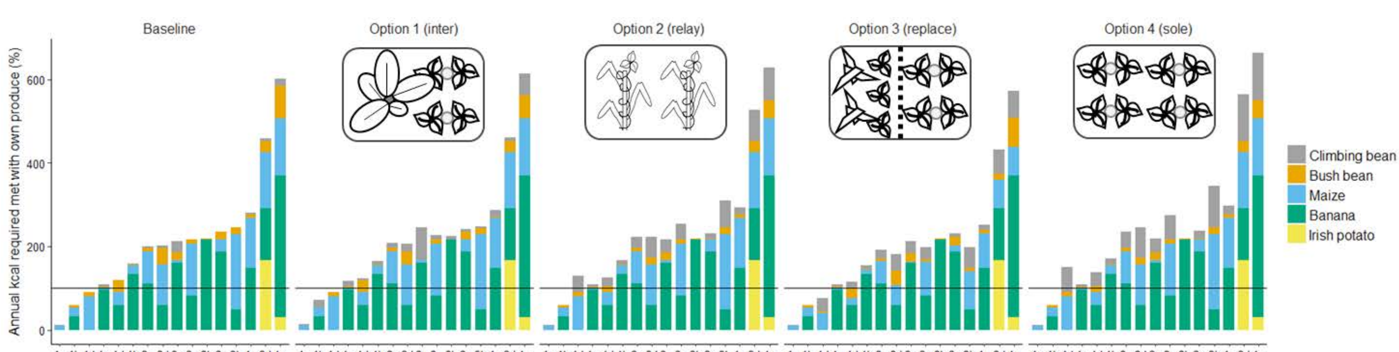

Figure 1: Food self-sufficiency (annual kcal required by household divided by kcal supplied by crops from farm (%)) per option. Numbers on the x-axis represent farm types 1-4, letters a-d the four farms within the type.

considerably larger because of the staking requirements for climbing bean. Only the maize stalks (Option 2) provide a 'free' sources of stakes. Despite the increase in costs, all options resulted in a larger profit than (maize +) bush bean cultivation. Income : cost ratios for climbing beans were not always more favourable. Returns to labour were larger for climbing bean cultivation in Options 1 and 4, but smaller in Option 2 and especially Option 3. All in all, climbing beans could make a great contribution in food self-sufficiency and income, provided that farmers are able to make the necessary investments. Reflection on these outcomes with farmers revealed that, in general, farmers found income more important than food self-sufficiency. Considering the increasing demand for climbing beans and resulting good market prices, farmers indicated they would have to struggle to find capital and labour, but if the beans did well they would be willing to make the additional effort.

Esther Ronner, Wageningen University & Research, The Netherlands (Click here for her 2016 update)

Reference
Marinus, W., 2015. Opportunities and constraints for climbing bean (*Phaseolus vulgaris* L.) cultivation by smallholder farmers in the Ugandan highlands: Developing a 'basket of options'. Wageningen University, Wageningen.

Understanding G_L x G_R interaction in common bean and chickpea in Ethiopia

Common bean (*Phaseolus vulgaris* L.) and chickpea (*Cicer arietinum* L.) are the most important grain legumes in Ethiopia. Most of the Ethiopian soils are deficient of soil nitrogen, thereby reducing crop production far below potential. However, common bean (hereafter referred to as "bean") and chickpea can form symbiotic associations with soil bacteria called rhizobia and fix atmospheric nitrogen inside a root nodule. The fixed nitrogen is then used for growth and development of the plant. Symbiotic nitrogen fixation is partly affected by the genotypes of the interacting legume and rhizobia.

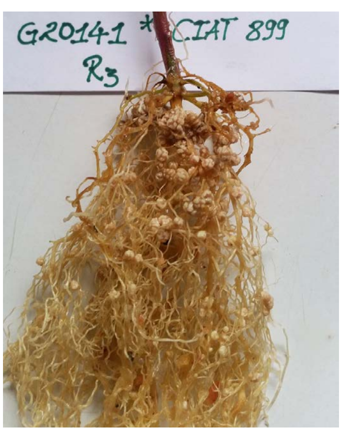

Figure 1. Nodulation of Bean genotype G20141 inoculated with CIAT899

As part of N2Africa-Ethiopia, this PhD project aims to investigate the legume genotype (G_L) x rhizobium genotype (G_R) interactions in chickpea and bean in terms of their symbiotic effectiveness. Bean and chickpea genotypes and rhizobium strains were selected based on their phylogenetic distances. The selected genotypes and strains were factorially combined and tested in modified Leonard Jars (Somasegaran and Hoben, 1994; Howieson and Dilworth, 2016) using an RCBD design with five replications. After 45 days of growth, plant phenotypes were assessed for nodulation (nod+/nod-) and nitrogen fixation (fix+/fix-), respectively. Plants with nod+/fix+ phenotypes were screened for further investigation in pots.

Rhizobium strains CIAT899 (Figure 1) and NAK-91 formed symbiotically effective nodules across all the tested bean genotypes, whereas the other strains had varied nodulation and N_2-fixation phenotypes (Figure 2). Some of the legume genotypes were nodulated by most of the strains tested, indicating that they can effectively fix nitrogen if inoculated by any of these strains.

In chickpea, the interactions between G_L and G_R were relatively uniform in their effects on nodulation and fixation phenotypes. Most of the strains were able to form effective nodules (Figure 3) on all of the tested chickpea genotypes (Figure 4). This implies intense competition among the soil

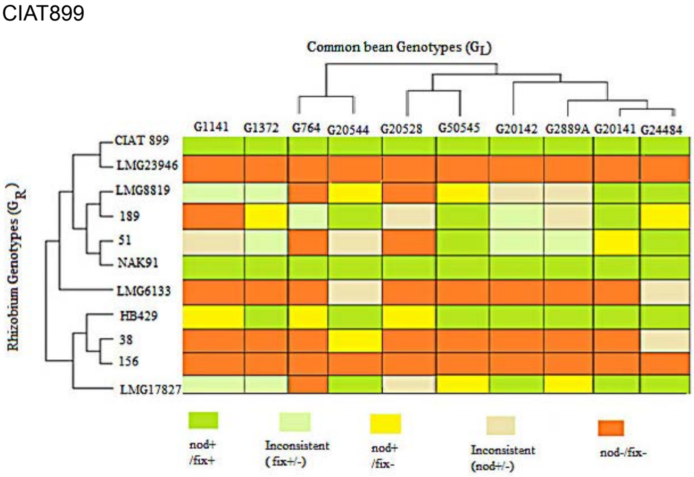

Figure 2. Nodulation and N_2-fixation phenotypic responses of G_L x G_R interaction in common bean

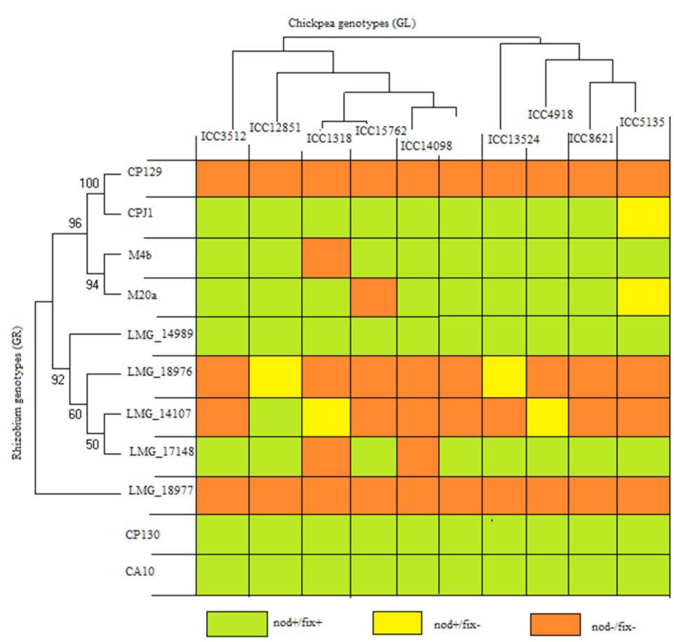

Figure 3. Nodulation and N_2-fixation phenotypic responses of G_L x G_R interaction in chickpea

Figure 4: Chickpea genotype ICC13187 inoculated with LMG14989

rhizobial populations to infect a given chickpea genotype. Based on the jar experiment, five bean genotypes (G1372, G20141, G20142, G20544 and G24484) and seven bean rhizobia (CIAT899, NAK-91, LMG17827, LMG8819, HB429, 51 (NAE-HB-12-N4) and 189 (NAE-HB-39-L1) were selected for further investigation in pot. The pot experiment (Figure 5) was set following the methods described in Howieson and Dilworth (2016). Similarly, seven chickpea strains (LMG14989, CA10, Cp130, CPJ1, M4b, LMG17148 and M20a) and 5 chickpea genotypes (ICC12851, ICC13524, ICC8621, ICC9434 and ICC6263) were selected and are now under investigation.

In conclusion, investigation of G_L x G_R interactions in jars helped to screen a number of rhizobium strains and legume genotypes and select the most promising ones for a follow-up pot experiment.

Figure 5: GxG interaction in bean in pots

Acknowledgement: I am very much grateful to Wageningen University, Hawassa University and N2Africa Project for technical, material and financial supports. I would also like to acknowledge CIAT for providing common bean genotypes and ICRISAT for providing chickpea genotypes.

Ashenafi Hailu Gunnabo, Wageningen University & Research, The Netherlands (Click here for his 2016 update)

References:

Somasegaran, P. and Hoben, H.J. (1994). Handbook for Rhizobia: Methods in Legume Rhizobium Technology. Springer-Verlag, New York.

Howieson, J.G. and Dilworth, M.J. (Eds.) (2016). Working with rhizobia. Australian Centre for International Agricultural Research (ACIAR), Canberra.

Maize-grain legume intercropping for enhanced resource use efficiency and crop productivity in the Guinea savanna of northern Ghana

Smallholder farmers in the Guinea savanna agroecological zone of northern Ghana practise maize-grain legume intercropping to mitigate the risks of crop failure in sole cropping, and to safeguard household food, nutrition and income security. The productivity of maize-grain legume intercrops is influenced by soil fertility status and the spatial arrangement of the intercrop components. Although maize-grain legume intercrops have been studied in the Guinea savanna, these have been limited to distinct alternate arrangements on experimental stations. The impact of soil fertility on intercrop productivity has not been studied in the Guinea savanna despite the large variability in soil fertility status observed in farmers' fields. Therefore, we studied the impact of different spatial arrangement of maize and grain legume intercrops (Figure 1) and soil fertility status on resource use efficiency, crop productivity and economic

Figure 1. Spatial arrangement of maize-grain legume intercropping patterns that were tested: (A) maize-legume sown within-row (mixed), (B) one row of maize alternated with one row of legume (1 to 1 rows) and (C) two rows of maize alternated with two rows of legume (2 to 2 rows)

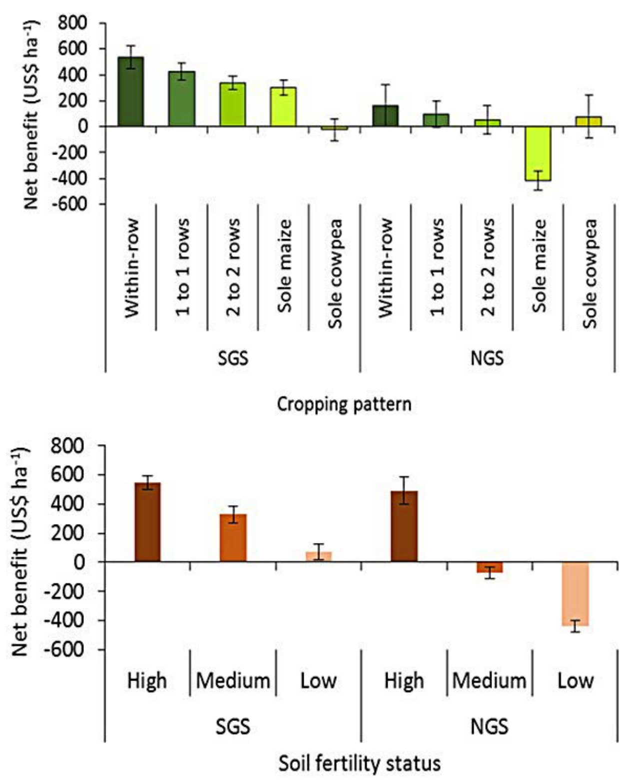

Figure 2. Net benefits as influenced by maize and cowpea cropping pattern and soil fertility status in the southern Guinea savanna (SGS) and northern Guinea savanna (NGS) of northern Ghana. Error bars indicate the standard error of mean.
Source: Kermah et al. (2017).

profitability under on-farm conditions in the southern and northern Guinea savanna agroecological zones of northern Ghana.

In Podcaster (no. 39), I presented the intercrop grain yields of cowpea and maize as affected by the spatial arrangement of the intercrops and soil fertility status while the full manuscript for publication was under preparation. The paper has now been published as:

Kermah, M., Franke, A.C., Adjei-Nsiah, S., Ahiabor, B.D.K., Abaidoo, R.C., Giller, K.E., 2017. Maize-grain legume intercropping for enhanced resource use efficiency and crop productivity in the Guinea savanna of northern Ghana. Field Crop Res. 213, 38-50.

Here I present the economic evaluation (Figure 2) of cowpea and maize intercrops and sole crops from the paper. The within-row intercrop pattern was more profitable than the distinct row arrangement. Intercropping maize and grain legumes generally led to larger net benefits compared with sole cropping of maize or a grain legume. Economic profitability of the cropping patterns declined with decreasing soil fertility. However, land equivalent ratios were greater in the low fertility fields, indicating that the intercrops used environmental resources more efficiently to produce grain yield in the low fertility fields (see paper). These results demonstrate that smallholder farmers in the Guinea savanna can intensify grain legume production by intercropping them with maize (largely the main crop) and preferably in a within-row arrangement to increase resource use efficiency, crop productivity and economic profitability.

Michael Kermah, Wageningen University & Research, The Netherlands

Enhancing the yield and quality of cowpea fodder through inoculation and phosphorus fertilizer application in northern Ghana

Introduction

Cowpea (*Vigna unguiculata*) is an important crop in the mixed crop livestock systems of northern Ghana since it supplies protein to the human diets, fodder to livestock, and it captures nitrogen into the farming system through biological nitrogen fixation. Cowpea fodder for feeding livestock is traded for cash and animal manure by farmers in northern Ghana. Cowpea grain and fodder yields have been increased through rhizobium inoculation and application of phosphorus fertilizers. However, there is little information about effects of inoculation and phosphorus fertilization on the quality of the fodder.

Objectives

- To evaluate the effect of inoculation and phosphorus fertilizer application on cowpea fodder yield and quality.
- To compare cowpea fodder yield and quality in the Southern Guineas savanna (SGS) and Northern Guinea savanna (NGS) agro-ecological zones (AEZ) of northern Ghana.

Approach

A split-plot design was used with one replicate in a farm in four different communities per agro-ecological zone. The treatments were cowpea varieties (Songotra, Padituya and Apagbaala) as main plot factor. The sub-plot factors were the combinations of inoculation and phosphorus fertilizer (inoculant only, phosphorus fertilizer only, phosphorus and inoculant combined and non-inoculated, non-fertilized control). Fodder yield was estimated after the last pod harvest by cutting the fodder on each plot (30 m^2) at ground level and weighing it. Sub-samples were taken for oven-drying for determination of dry weight. Fodder was analysed for *in-vitro* organic matter digestibility (IVOMD) using Near Infrared Reflectance Spectroscopy (NIRS) and analytical chemistry for calibration. The linear mixed model procedure in GenStat (18th Edition, VSI international Ltd) was used for data analyses. Differences between means were considered to be significant at a confidence interval of $P<0.05$.

Key results

Fodder yields were significantly higher in SGS than NGS. Padituya variety produced the highest average fodder yield

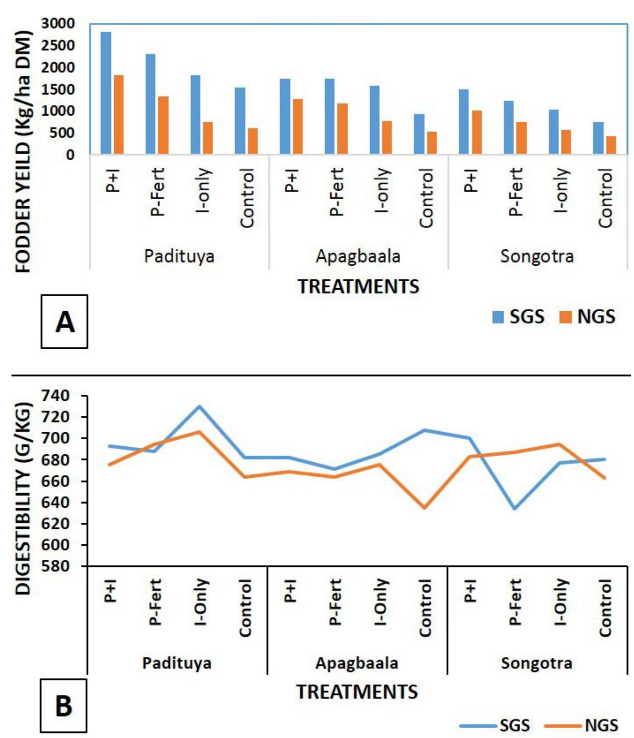

Figure 1. Effect of rhizobium inoculation and phosphorus fertilizer application on fodder yield (**A**) and digestibility (**B**) of three cowpea varieties in SGS and NGS of northern Ghana

(1627 kg/ha) with both inoculation and phosphorus fertilizer application while Songotra produced the least fodder (908 kg/ha) in the control treatment in the two AEZ (Figure 1A). There was also significant interaction between AEZ and phosphorus fertilizer application (P-fert) indicating that P-fert performed differently in the two AEZ.

In SGS, there were significant varietal differences for *in-vitro* organic matter digestibility (IVOMD). In SGS inoculation increased IVOMD while phosphorus fertilizer application had negative effect on IVOMD (Figure 2B). Inoculation in general improved digestibility significantly in the two AEZ with some significant interactions among AEZ, P-fert and inoculation (P<0.007).

Significance

The current study demonstrated that rhizobium inoculation and application of phosphorus fertilizer had influence on cowpea fodder yield and IVOMD differently in the AEZ of northern Ghana. Padituya variety produced the highest fodder with best quality indicators in the two AEZ. Farmers applying the technology of rhizobium inoculation and phosphorus fertilizer application to the right cowpea varieties would not only benefit from yield increases but fodder quality is also enhanced for use in animal production in northern Ghana.

Daniel Brain Akakpo, Wageningen University & Research, The Netherlands (Click here for his 2016 update)

Exploring options to improve soyabean yields in Mozambique

Amaral Machaculeha Chibeba, from Mozambique, was awarded a PhD fellowship by the Wageningen University in 2012 under the N2Africa Project. The four-year studies were conducted under the supervision of Dr. Maria de Fátima Guimarães from Londrina State University (Brazil), Dr. Mariangela Hungria from Embrapa (Brazil) and Dr. Stephen Kyei-Boahen from IITA (Mozambique) between June 2012 and September 2016. During the last 12 months the awardee worked on revising two articles of his already defended PhD Thesis. Both articles have just been published with open access by Agriculture, Ecosystems & Environment.

Chibeba A.M., Kyei-Boahen, S., de Fátima Guimarães, M., Nogueira, M.A., Hungria, M., 2017. Isolation, characterization and selection of indigenous *Bradyrhizobium* strains with outstanding symbiotic performance to increase soyabean yields in Mozambique. Agriculture, Ecosystems & Environment, 246, 291–305.

In this article, 105 isolates obtained from nodules of promiscuous soyabean grown at 15 sites in Manica (4), Nampula (2), Tete (6) and Zambézia (3) provinces, in Mozambique, were screened for N_2-fixation effectiveness in the greenhouse in Brazil along with five commercial strains. Eighty-seven isolates confirmed the ability to form effective nodules on soyabean and were used for genetic characterization by rep-PCR (BOX) and sequencing of the 16S rRNA gene, and also for symbiotic effectiveness. BOX-PCR fingerprinting revealed remarkable genetic diversity, with 41 clusters formed, considering a similarity level of 65%. The 16S rRNA analysis assigned the isolates to the genera *Bradyrhizobium* (75%) and *Agrobacterium/Rhizobium*

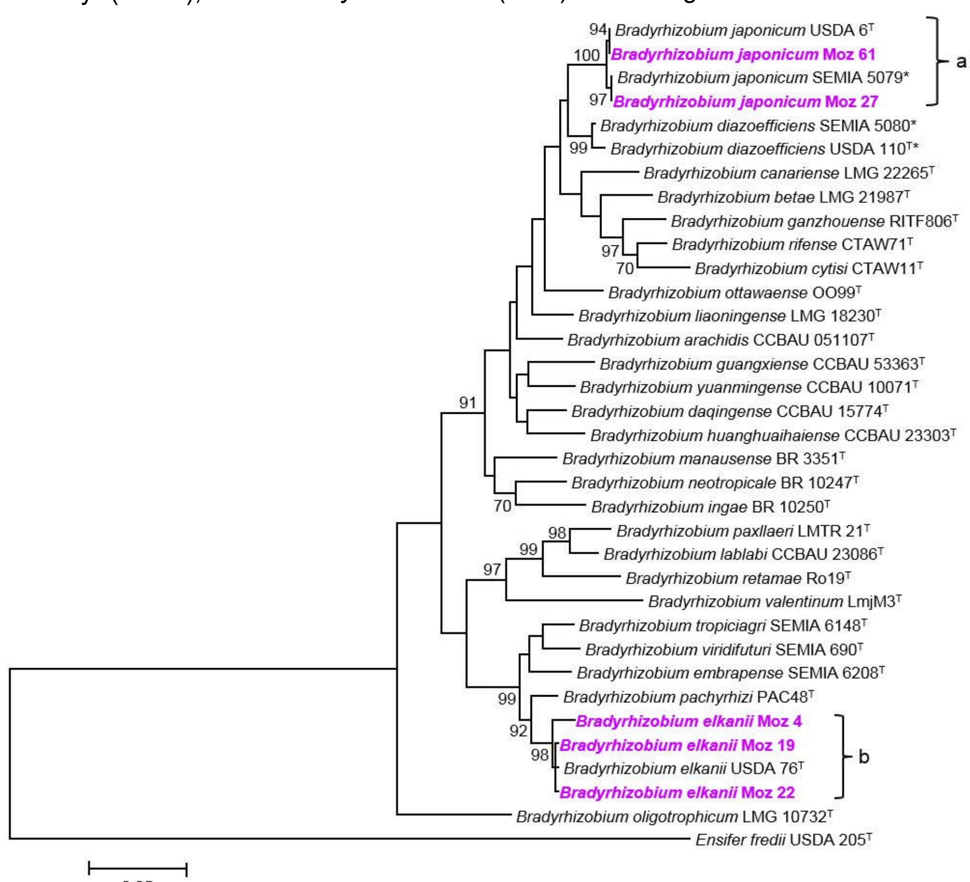

Figure 1. Maximum – likelihood phylogeny based on concatenated gene sequences [dnaK (223 bp), glnII (480 bp), gyrB (419 bp) and recA (375 bp)] showing the relationships among five indigenous rhizobial isolates from Mozambique (in bold purple) with type (^{T}) and reference strains used in commercial inoculants, *B. elkanii* SEMIA 587 and SEMIA 5019, *B. japonicum* SEMIA 5079, and *B. diazoefficiens* SEMIA 5080 and USDA 110 (with an asterix). *Ensifer fredii* USDA 205^T was included as an outgroup. Only bootstrap confidence levels > 70% are shown at the internodes. The scale bar indicates 5 substitutions per 100 nucleotides; a and b represent the clustering of the five best nitrogen fixer strains from Mozambique (Source: Chibeba, *et al*. 2017).

(25%). Great variability in symbiotic effectiveness was detected among the indigenous rhizobia from Mozambique, with ten isolates performing better than the commercial strain *B. diazoefficiens* USDA 110, the best reference strain, and 51 isolates with lower performance than all reference strains. Five isolates, three (Moz 4, Moz 19 and Moz 22) belonging to the superclade *B. elkanii* and two (Moz 27 and Moz 61) assigned to the superclade *B. japonicum*, consistently showed high symbiotic effectiveness, suggesting that the inoculation with indigenous rhizobia adapted to local conditions represents a possible strategy for increasing soyabean yields in Mozambique. Phylogenetic position of the five elite isolates was confirmed by the MLSA with four protein-coding housekeeping genes, *dnaK*, *glnII*, *gyrB* and *recA* (Figure 1).

Chibeba A.M., Kyei-Boahen, S., de Fátima Guimarães, M., Nogueira, M.A., Hungria, M., 2017. Feasibility of transference of inoculation-related technologies: A case study of evaluation of soyabean rhizobial strains under the agro-climatic conditions of Brazil and Mozambique. Agriculture, Ecosystems & Environment, online 14 July 2017, In Press, Corrected Proof

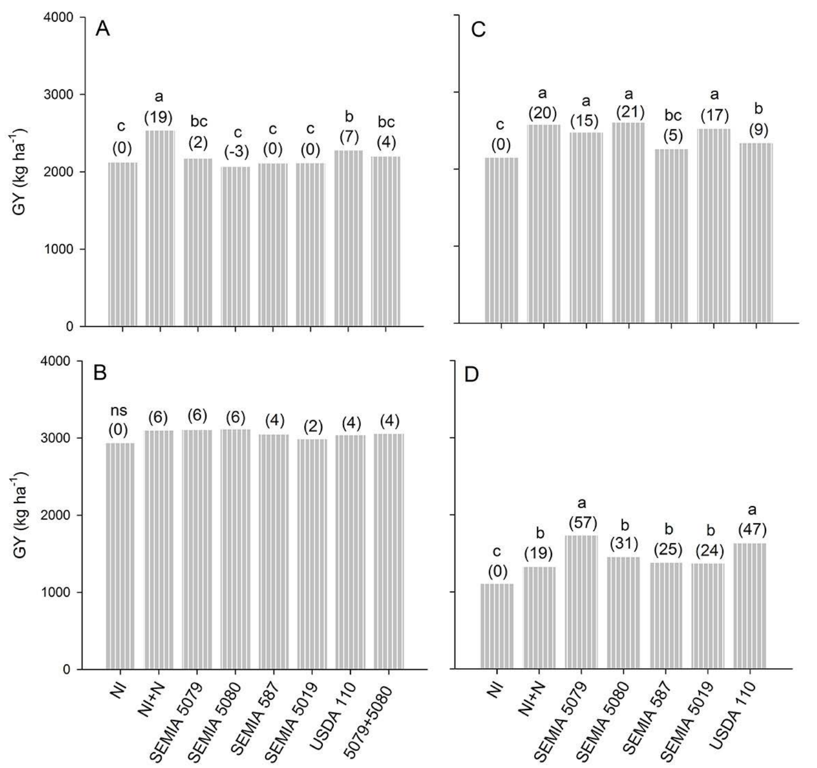

Figure 2. Grain yield (GY, kg ha^{-1}) of soyabean, grown at four locations in Brazil in the 2013/2014 (A) and 2014/2015 crop seasons (B) and at five locations in Mozambique in the 2013/2014 (C) and 2014/2015 (D) crop seasons. NI, Non-inoculated and non-N-fertilized control; NI+N, non-inoculated control with 200 kg of N ha^{-1}; Inoculated with: SEMIA 5079, *B. japonicum* SEMIA 5079; SEMIA 5080, *B. diazoefficiens* SEMIA 5080; SEMIA 587, *B. elkanii* SEMIA 587; SEMIA 5019, *B. elkanii* SEMIA 5019; USDA 110, *B. diazoefficiens* USDA 110; 5079+5080, *B. japonicum* SEMIA 5079 and B. diazoefficiens SEMIA 5080. Bars are means of six (Brazil) or five (Mozambique) replicates and when followed by same letter in the same country and crop season are not statistically different ($p \leq 0.10$, Duncan); ns signifies no statistical differences were detected ($p \leq 0.10$, Duncan); numbers in parentheses represent percentage increases in relation to the NI treatment (Source: Chibeba, *et al.* 2017).

Here, the performance of five strains (four Brazilian and one North American) in the 2013/2014 and 2014/2015 crop seasons in Brazil and Mozambique was evaluated. The experimental areas were located in relatively similar agro-climatic regions and had soyabean nodulating rhizobial population ranging from <<10 to 2 ×10^5 cells g^{-1} soil. The treatments were: (1) NI, non-inoculated control with no N-fertilizer; (2) NI + N, non-inoculated control with 200 kg of N ha^{-1}; and inoculated with (3) B*radyrhizobium japonicum* SEMIA 5079; (4) *B. diazoefficiens* SEMIA 5080; (5) *B. elkanii* SEMIA 587; (6) *B. elkanii* SEMIA 5019; (7) *B. diazoefficiens* USDA 110; (8) SEMIA 5079 + 5080. The best inoculation strains across locations and crop seasons in Brazil and Mozambique were SEMIA 5079, SEMIA 5080 and USDA 110 (Figure 2) suggesting that the transference of inoculation technologies between countries is feasible.

Dr. Chibeba is presently working for IITA – Mozambique, since January 2017, as Postdoctoral Fellow in Agronomy and Soil Microbiology. His main responsibility is to conduct multi-location field trials with the promising indigenous rhizobial isolates identified in Brazil (first trial above) to confirm their potential use in inoculants for soyabean in Mozambique.

Amaral Chibeba, State University of Londrina (UEL), Brazil (Click here for his 2016 update)

Symbiotic performance of soyabean root nodule bacteria (RNB) recovered from Zimbabwe

Soyabean is an important crop in the agriculture-led economy of Zimbabwe and production is supported by inoculation with rhizobia. Rhizobia are soil bacteria that have the ability to form symbioses with legumes and fix nitrogen within novel structures called nodules. This obviates the need for nitrogen fertilizer, which is expensive and difficult to manage. While rhizobia are found in many soils, any given population must be screened in order to select individual isolates with superior nitrogen fixation abilities and other desirable traits. An elite rhizobia inoculant strain of Japanese origin, USDA 110, is used for inoculation of soyabean in Zimbabwe. However, it does not persist very well in farmers' fields.

Indigenous rhizobia often have superior ability to survive under their native environments. Inoculation of elite exotic strains into soils that harbour indigenous rhizobia may result in new rhizobia that have the environmental adaptation of local rhizobia and the nitrogen fixation of elite inoculant strains, through horizontal gene transfer. The most significant output from my study would be a recommendation of such rhizobia inoculant strains to replace the elite USDA 110 in order to sustainably increase the yield of inoculated soyabean in Zimbabwe.

In 2011/12 agriculture season, I isolated soyabean RNB from fields that had been inoculated with USDA 110 at least five years prior. To answer the question of diversity and phylogeny of soyabean root nodule bacteria in Zimbabwe, I characterised one hundred and thirty-seven (137) isolates in the laboratory. Only eighteen belong to the same species as inoculant strain USDA 110. The remaining eighty seven percent (87 %) belong to a combination of three species. We conclude that there are at least three species of soyabean RNB that are indigenous to Zimbabwe, and that five years after inoculation, indigenous populations outnumber those of inoculant strains.

I evaluated the same isolates for nitrogen fixation under glasshouse conditions. The isolates range from poor fixers to isolates that outperform USDA 110. I identified the top 10 % nitrogen fixers for further testing under field conditions and onward recommendation for use as inoculant strains. In the last agriculture season, which spanned October 2016 to March 2017, I set up three experiments to evaluate performance under field conditions. Each experiment consisted of eight test isolates from my study, a non-inoculated control and a positive control inoculated with the inoculant strain USDA 110. All treatments were replicated four times. Figure 1 shows the dry weights of soyabean stover, evaluated before physiological maturity when the

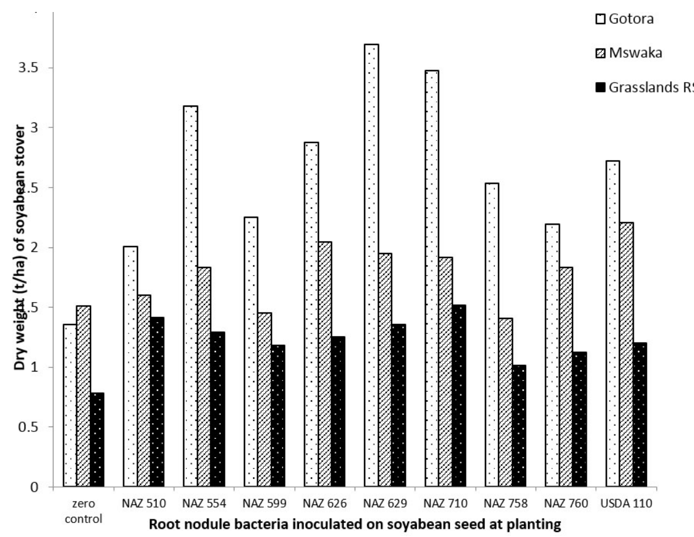

Figure 1. Dry weight of soyabean biomass inoculated with soyabean root nodule bacteria recovered in Zimbabwe

grain yield becomes available. The stover is correlated to nitrogen fixation and grain yield.

The differences in stover recovered across the sites may be due to the variation of rainfall amounts received. Gotora site had the highest biomass accumulation; followed by Muswaka and GRS had the least biomass accumulation. Preliminary results of stover accumulation in plots inoculated with isolates NAZ 629, NAZ 710, NAZ 626 and NAZ 554 exceeded the biomass from plots inoculated with USDA 110 and suggest that these isolates can be recommended for rhizobia inoculation.

Mazvita Chiduwa, Murdoch Univeristy (Click here for her 2016 update)

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

One of my PhD research activities included trials that assessed the effect of mineral fertilizers (N, P, K and their combination) and manure (0, 2 and 5 t ha^{-1}) application on climbing bean yields. This study was carried out in two sites of the Northern Province of Rwanda, which is the major climbing bean growing area in the country. As part of this work, I evaluated the response of mineral fertilizer to manure application, the role of fertilizer and manure on shoot N and P uptake.

Manure application led to a substantial increase in the grain yield with response of fertilizer to manure application ranging from 1.0-1.7 t ha^{-1} (Table 1). Greater responses were observed in Muko than in Kinoni. On average, greater response of fertilizer to manure addition was achieved when manure was used together with N or NPK fertilizers though there was no significant difference in Kinoni site.

Shoot N and P uptake as affected by inputs application

Shoot N and P uptake were improved by input application and were on average greater in Muko than in Kinoni. In both sites, greater uptake was achieved in plots that received

Table 1. Climbing bean grain yield (t ha^{-1}) and response of fertilizer to 5 t ha^{-1} manure application at Kinoni and Muko sites.

Sites	Fertilizer	No manure	With manure	Response to manure
Kinoni				
	N	2.3	3.5	1.2
	P	2.1	3.1	1.0
	K	1.9	3.1	1.2
	NPK	2.4	3.9	1.5
	SED	*ns*	*ns*	*ns*
Muko				
	N	3.3	4.9	1.6
	P	3.5	4.8	1.3
	K	3.2	4.6	1.4
	NPK	3.7	5.4	1.7
	SED	*0.09*	*0.07*	*0.12*

SED: Standard error of difference between treatment means both fertilizer and manure, and were least in plots that had not received any amendment. On average 30 kg P ha^{-1} and 5 t manure ha^{-1} applied together increased N uptake from 48.5 to 106.3 kg N ha^{-1} in Kinoni and from 45.9 to 128.3 kg N ha^{-1} in Muko. Application of 30 kg P ha^{-1} and 5 t manure ha-1 also increased P uptake from 6.1 to 12.4 kg P ha^{-1} in Kinoni and from 5.3 to 17.9 kg P ha^{-1} in Muko (Table 2). This indicated that there was increased performance of the plant at both sites, hence increased nutrient uptake. Increased N and P uptake in treated plots compared to control plots may be a result of the nutrient supply including N and P, and greater root system development leading to exploitation of a big volume of soil.

Edouard Rurangwa, Wageningen University & Research, The Netherlands, (Click here for his 2016 update)

Table 2. Shoot N and P uptake as affected by input treatments.

Sites / Fertilizer (kg ha^{-1})	Manure (t ha^{-1})	Biomass (t ha^{-1})	Shoot N uptake (kg ha^{-1})	Shoot P uptake (kg ha^{-1})
Kinoni				
0P	0	1.6	48.5	6.1
0P	5	3.2	89.8	11.6
30P	0	2.1	63.5	7.5
30P	5	3.5	106.3	12.4
Mean / Site		2.6	77	9.4
SED (Fertilizer)		*0.1*	*3.7*	*0.7*
SED (Manure)		*0.1*	*4.4*	*1.3*
Muko				
0P	0	1.4	45.9	5.3
0P	5	3.2	96.1	13.9
30P	0	2.1	68.7	9.0
30P	5	4.1	128.3	17.9
Mean / Site		2.7	84.7	11.5
SED (Fertilizer)		*0.1*	*3.7*	*0.8*
SED (Manure)		*0.1*	*7.8*	*1.1*

Nutritional benefits of improved grain legume cultivation in Ghana and Kenya

My first paper '*Grain legume cultivation and children's dietary diversity in smallholder farming households in rural Ghana and Kenya*' was just published in Springer's journal Food Security! Currently, I am finalising my second paper sharing results of our dietary gap assessment in northern Ghana. I analysed whether the dietary requirements of Ghanaian households were met by their own households' production, both on the basis of total nutrient requirements based on gender, age or physiological status (pregnant or breastfeeding) of individual household members (comparing quantity of nutrients needed with nutrient produced) and on the basis of local dietary guidelines (comparing quantity of foods needed with foods produced). We found that household production covered macronutrient needs (except for fat) but did not cover most micronutrient needs (especially calcium, vitamin A, vitamin B12 and vitamin C). Many households did not cover their grain and legume needs (40% of the households covered less than 100% of their needs) and no households covered their vegetable needs by their own production. Comparison of the monetary value of a household's total production with the costs of that household's total food needs, showed that more than one third of the households were not able to cover their food needs if all farm income was spent on food.

In addition, we identified the percentage of food group requirements covered by their production at district level in Karaga district and national level in Ghana. At household level, we used the median instead of the mean because of a few strong outliers. At district level, we used the mean as it does represent the potential coverage at district level (high production levels of foods from the different food groups of a few households may be available at local markets). At national level, we used kg of national food availability per capita in relation to the recommended food per capita (based on South African food-based dietary guidelines as there are no national guidelines for Ghana). We found that grain needs were amply covered overall at household (a median (IQR) of 150 (244) but with 40% of individual households with a coverage below 100%), district and national level, see Figure below. Legume needs were also covered at household and district level but not at national level. Vegetable needs were not covered at all of these levels.

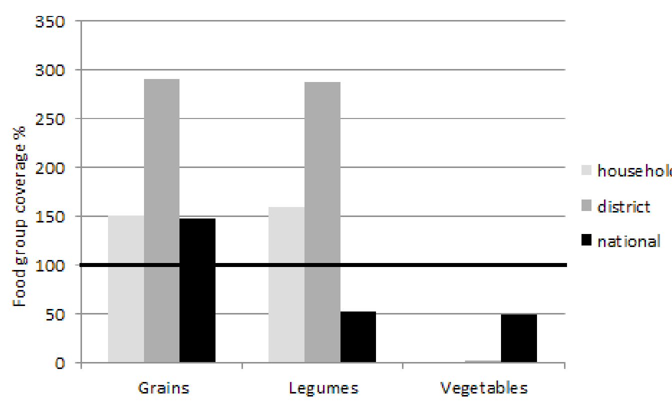

Figure. Percentage of food group requirements covered by their production at household and district level in Karaga district and national level in Ghana. Values at household level are in median (IQR) (median is used instead of the mean because of a few strong outliers); values at district level are in mean (SD); and values at national level are percentages coverage (kg national food availability per capita/recommended food per capita (South African food-based dietary guidelines)*100).

The assessment of dietary gaps may help to identify key crops that require a boost in terms of production and market development to make them better available and more affordable. The availability of diverse, nutrient-dense food is an essential first step towards meeting dietary goals. It should ultimately be reinforced by improvements in food distribution, accessibility and utilization. In October, I will present both papers at the 21st International Congress of Nutrition in Argentina.

Ilse de Jager, Wageningen University & Research, The Netherlands (Click here for her 2016 update)

Co-learning using NUANCES-FARMSIM in Kenya and Uganda - A collaboration between Humidtropics, MAIZE and N2Africa

A PhD project using farming systems analysis in Kenya and Uganda

My PhD research does not solely focus on legumes, but uses legumes as one of the options to sustainably increase farm-level production. The first field activities (and my PhD project) started in August 2016 with co-learning workshops in western Kenya and activities in western Uganda will follow early 2018. I am not completely new to N2Africa as I did both my MSc-theses within the project and also worked as a research fellow for N2Africa in the year before the start of my PhD. Here I will introduce how my PhD project uses methods of farming systems analysis – using NUANCES-FARMSIM in co-learning cycles – to assess how legumes and other options can contribute to a sustainable increase in production, and I will show some first results.

NUANCES-FARMSIM as a tool for co-learning

NUANCES-FARMSIM is a crop-livestock model with a user-friendly interface. It can simulate the complex interactions at farm-level and assess short-term yields and longer-term (10-15 years) trends in productivity and soil fertility (Figure 1). The decision space of smallholder farmers also depends on factors like availability and affordability of technologies and for instance cultural norms: factors that are difficult to model. Iterative cycles of co-learning in participatory modelling exercises with farmers and researchers can help to understand the decision space of farmers. Scenario outputs of NUANCES-FARMSIM for farms with different socio-economic characteristics, e.g. farm types, can facilitate these sessions and inform decision-making of smallholder farmers.

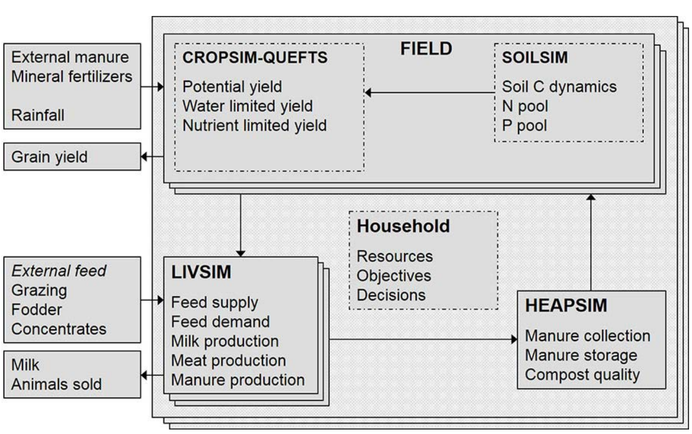

Figure 1. Relational diagram of NUANCES-FARMSIM (farm level) and its sub-models FIELD (fields), LIVSIM (livestock) and HEAPSIM (manure heap) (Van Wijk et al. 2009)

First co-learning cycles in western Kenya

Two contrasting locations (in terms of agro-ecological conditions and market access) in maize-based systems in western Kenya were selected: Vihiga and Busia. Two sub-locations (treatment and control group) were selected with each 12 farmers (of 3 farm types). Farmers of both groups receive a voucher of USD 100 each season for which they can buy selected maize, soyabean, groundnut (from the 2nd season onwards), bush bean, and/or dairy inputs. The treatment group takes part in a co-learning workshops each season, whereas the control group does not take part in workshops.

Each season the research uses co-learning as part of a full DEED cycle (Figure 2.), using the following steps:

- Farming systems were *described* using a detailed farm characterization survey (including soil sampling) as a baseline (2016A) and are *described* in monitoring surveys during the past two (2016B and 2017A) and up-coming seasons;
- Current yields and production systems were *explained* using information from literature and model results;
- *Explorations* of different scenarios per farm type and how this results in farm (management) *designs* were discussed during the co-learning workshops. Soil fertility gradients proved a good basis for discussing options with farmers.

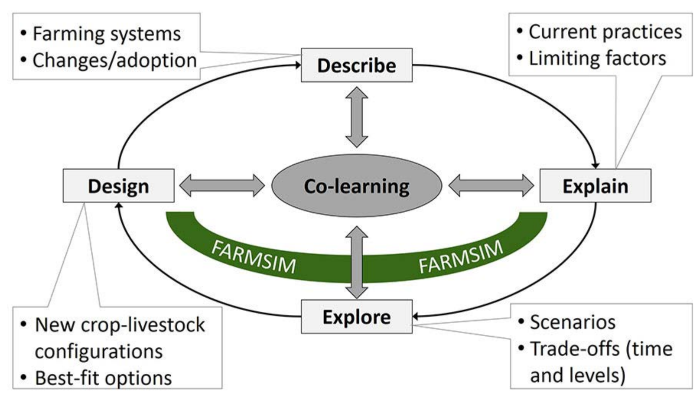

Figure 2. Using NUANCES-FARMSIM in the DEED-cycle of Describe (D), Explain (E), Explore (E), and Design (D) for Co-learning. Adopted from Descheemaeker et al. (2016)

Some results

First results showed an unexpected increase in cultivated area (Table 1). Soyabean cultivation and fertilizer application also increased as a result of the increased accessibility due to the voucher and inputs brought in the workshops. Groundnut was only included in the voucher in the second season (2017A) and was liked as an alter-


Figure 3. Discussing options for improving farm production with farmers in Vihiga

native option for soyabean in Vihiga. Fertilizer application rates became more moderate in the second season due to an increase in the area it was applied on (discussed in the workshops). Differences between groups are expected to appear in coming seasons.

Future cycles: exploring farm level trade-offs:
- Long-term vs. short term benefits;
- Optimization of land allocation (i.e. maize vs. soyabean vs. Napier grass);
- Transformations towards higher production levels and more sustainable farming systems;
- Starting a similar series of co-learning cycles in banana-based systems in western Uganda.

Wytze Marinus, Wageningen University & Research, The Netherlands

References:
Descheemaeker *et al*., (2016). Climate change adaptation and mitigation in smallholder crop–livestock systems in sub-Saharan Africa: a call for integrated impact assessments, Exp Agric 1–22;
Van Wijk *et al,* 2009. Identifying key entry-points for strategic management of smallholder farming systems in sub-Saharan Africa using the dynamic farm-scale simulation model NUANCES-FARMSIM. Agric Syst 102, 89–101.

Table 1. First farm level results (averages across farms) for treatment and control groups in Vihiga and Busia

.	Vihiga Treat	Control	Busia Treat.	Control
# households	12	12	12	12
Cultivated area (ha)				
2016A	0.30	0.36	0.87	0.65
2016B	0.34	0.41	0.87	0.77
2017A	0.38	0.48	0.94	0.94
Soyabean (% cult. area)				
2016A	0	0	0	0
2016B	14	7	9	11
2017A	3	3	6	3
Groundnut (% cult. area)				
2016A	1	0	4	3
2016B	0	3	4	5
2017A	7	3	2	5
Fertiliser N application				
2016A Area (ha)	0.09	0.16	0.32	0.29
Rate (kg ha^{-1})	101	133	59	31
2016B Area (ha)	0.20	0.28	0.58	0.50
Rate (kg ha^{-1})	166	138	56	71
2017A Area (ha)	0.25	0.33	0.66	0.72
Rate (kg ha^{-1})	94	96	51	50

Understanding the role of Public-Private Partnerships in overcoming institutional barriers to technology adoption

N2Africa tests and promotes technologies to enhance legume productivity including improved legume seeds, inoculant, phosphorus fertilizer and improved practices. Adoption by smallholders is hindered by a range of institutional, socioeconomic and biophysical barriers. In line with current thinking on market-based development, Public-Private Partnership (PPP) interventions are used by N2Africa to overcome barriers to adoption. A knowledge gap exists concerning the design and effectiveness of PPPs.

I started my PhD studies earlier this year. Putting together theories from economics and marketing with literature on PPPs, we constructed a conceptual framework to better understand smallholders' adoption decisions of technologies (see Figure 1).

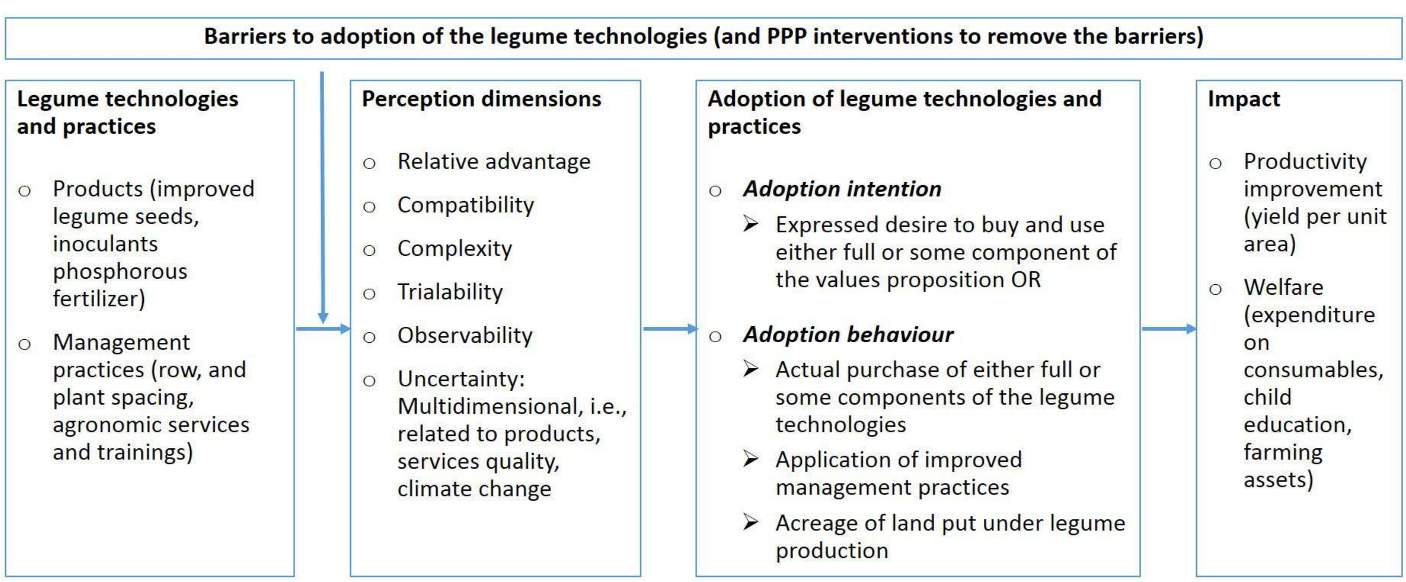

Figure 1. A conceptual framework for smallholders' legume technology adoption and its impact

To achieve the intended impact, smallholders need to adopt the technologies. This depends on their perceptions based on exposure to N2Africa dissemination activities. This thesis research (a) explores and identifies adoption barriers, (b) deepens our understanding of the adoption process through exploring the influence of the adoption barriers on smallholders' perceptions, (c) identifies and develops the PPP interventions that can enhance the adoption behaviour of smallholders, and (d) evaluates the welfare impacts of increasing legume productivity. The first qualitative study is being conducted using a case study methodology to build a theoretical background for the relationship that might exist between the adoption barriers and smallholders' perceptions. This will lay a background for further studies. Results of the case studies will be communicated in forthcoming podcaster issues.

Tamiru Amanu, International Livestock Research Institute, Ethiopia and Wageningen University & Research, The Netherlands

Participatory approaches to smallholder crop diversification in Malawi

My research started as a legume agronomist at the International Institute of Tropical Agriculture in Malawi. Two years of on-farm participatory research with smallholder farmers resulted in two publications. The first paper 'Participatory research to close the soybean yield gap on smallholder farms in Malawi' was published in Experimental Agriculture in 2016. A combination of inoculation, inorganic fertilizer (10 N, 8 P, 20 K in kg ha^{-1}), and 6 t ha^{-1} compost manure increased yields from 0.86 t ha-1 under farmers' practice to 1.56 t ha^{-1} and resulted in average profits of 222 US\$ ha^{-1}. Increased plant populations and biocide spraying also resulted in substantial yield increases. Low investment costs make inoculants, compost manure and increased plant populations interesting options, whereas adoption of inorganic fertiliser application in soyabean may be limited due to high costs and low value-cost ratios. The farmers ranked eight technologies in descending order of preference as 1. Early planting 2. Plant population 3. Variety choice 4. Compost manure 5. Weeding 6. Inoculant 7. Fertilizer and 8. Spraying. Our participatory research approach (Figure 1) demonstrated that there is a wide range of technologies with different levels of human and financial investment costs that smallholder farmers can adopt to enhance their soyabean yields and profits.

The second paper 'Understanding variability in the benefits of N_2-fixation in soybean-maize rotations on smallholder farmers' fields in Malawi' was published in Agriculture, Ecosystems and Environment in May 2017. Biological nitrogen fixation (BNF) was quantified with the natural

Figure 1. Participatory evaluation of soyabean crop and nutrient management practices in Salima, Malawi

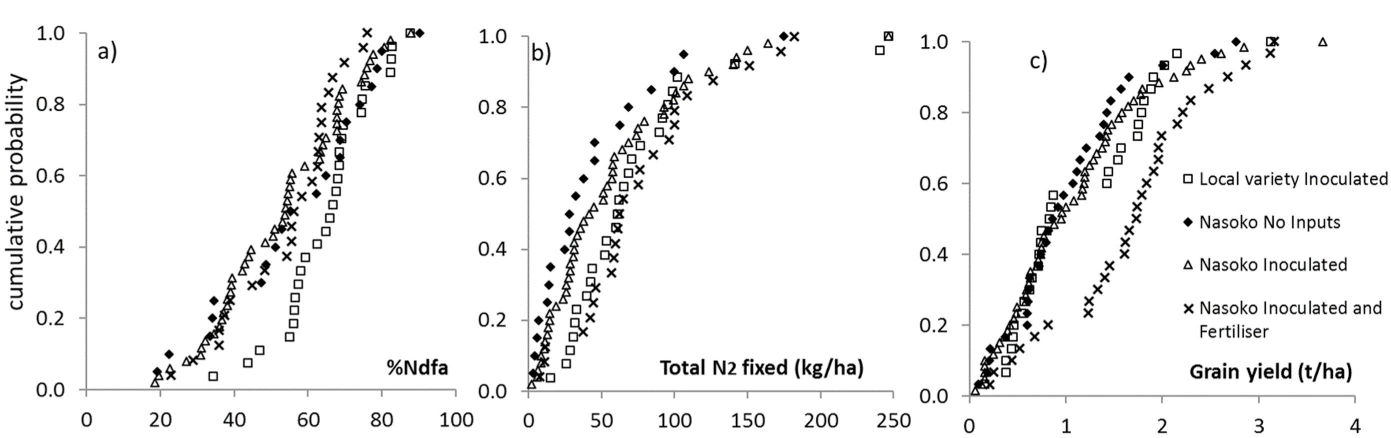

Figure 2. Cumulative probability charts of a) Percentage of Nitrogen derived from the atmosphere (%Ndfa) by soyabean, b) total quantity of N_2 fixed and c) soyabean grain yields

abundance method in 150 farmer-managed soyabean plots under different varieties and inputs in Dowa, Mchinji and Salima districts of Malawi. The yield effect on subsequent maize was compared with continuous maize cultivation. There was large variability in the percentage of N derived from the atmosphere (%Ndfa), total N_2 fixed and soyabean grain yields (Figure 2). N_2-fixation depended on a range of genetic, environmental, management and socio-economic factors. Average yield in continuous maize was 2.5 t ha^{-1}, while maize after soyabean produced 3.5 t ha^{-1} (139 % of continuous maize). More productive and wealthier farmers benefitted most from soyabean-maize crop rotation. Our results suggest that soyabean-maize rotations should be promoted with integrated soil and crop management. Although my research was not directly funded by N2Africa, I linked up with Linus Franke and Ken Giller who supervised my analysis and writing – and my results contributed to knowledge generation used within the project.

I am now employed by CIP and conducted research on a yield gap analysis for orange-fleshed sweet potato in Malawi (manuscript submitted to Field Crops Research in September 2017), and started a final paper on crop diversification with legumes and root and tuber crops.

Daniel van Vugt, International Potato Center (CIP), Malawi

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- Achieving sustainable cultivation of grain legumes Volume 1
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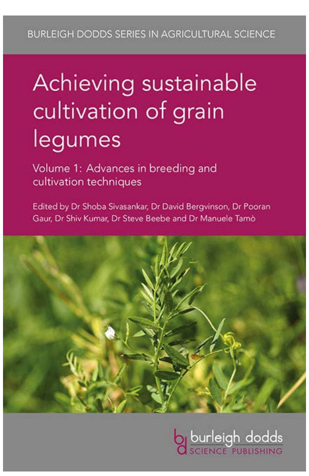

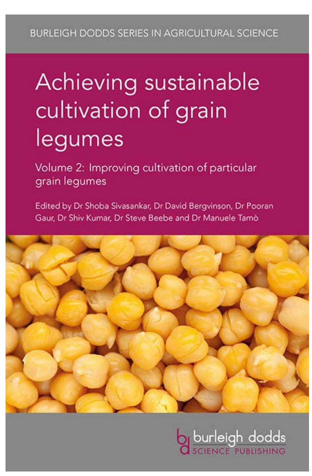

Both volumes, edited by Dr Shoba Sivasankar (Director of both the CGIAR Research Program on Grain Legumes and the Research Program on Dryland Cereals, based at ICRISAT in India) are due to publish this November. This major two-collection reviews the wealth of recent research on improving cultivation of this major crop. The first volume ranges from plant physiology and breeding through to better cultivation techniques. Volume two focusses on improving the cultivation of particular grain legumes, starting with common beans, chickpeas, lentils, soybeans and groundnuts. A second group of chapters discusses cowpea, faba beans and pigeonpea;.

Recent publications also of interest:

- Achieving sustainable cultivation of maize Volume 1;
- Achieving sustainable cultivation of maize Volume 2;
- Achieving sustainable cultivation of wheat Volume 1;
- Achieving sustainable cultivation of wheat Volume 2;
- Achieving sustainable cultivation of cassava Volume 1;
- Achieving sustainable cultivation of cassava Volume 2.

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