N2Africa Podcaster no. 57
PhD Student special

July and August 2019

Introduction

While we are busy with a range of studies assessing the impacts of N2Africa across the different countries, there are still many ongoing PhDs who are writing up their theses and publishing their work. To date 9 have completed their PhDs, some have submitted their theses and are awaiting examination and some who started later are still conducting field and laboratory research. As part of the impact studies of N2Africa I was delighted to learn that we have already hosted a total of 95 MSc thesis students.

As you will see the topics of the students vary widely – covering the whole scope of the legume-rhizobium symbiosis. Scales studied range from the diversity of the symbiotic bacteria (rhizobia) in soil, to field agronomy, livestock feeding, human nutrition, whole-farm studies, public-private partnerships, value chains, use of ICT and village level/ community analyses. We have organised the updates by country and I'm sure there is something to interest everybody! In the next Podcaster we will bring together results from the impact studies and if you have outputs or idea you'd like to share please do contact us.

Ken Giller

Focus group discussion in northern Ghana, June 2019. See article on page 8

Genetic diversity of indigenous rhizobia nodulating soyabean in grassland and cultivated fields of South Kivu, D.R.Congo.

We studied the genetic diversity of indigenous rhizobia nodulating soyabean in South Kivu province of D.R.Congo in order to compare the diversity in grassland and cultivated farms but also to identify indigenous rhizobia with potential of increasing soyabean'BNF and productivity. Soyabean (*Glycine max*) is an important crop worldwide and especially in Democratic Republic of the Congo, promoted since 1990 to deal with high malnutrition induced by political strife (Kismul et al., 2015).

This study examined the genetic diversity and nitrogen fixation potential of indigenous soyabean nodulating rhizobia (SNR) isolated from cultivated fields and grassland of South Kivu. Seventy SNR isolated from nodules of cultivated and non-cultivated legumes in Uvira, Walungu and Katana territories of South Kivu and a commercial strain (USDA 110) were analysed for genetic diversity based on *16s rRNA, recA, glnII-2* and *glnII-12* genes.

Based on all studied genes phylogenies, the results showed that indigenous SNR strains were highly diverse. In addition to the most the reported genus nodulating soyabean *Bradyrhizobium* and *Rhizobium*, other strains were identified namely *Kosakonia*, *Bacillus*, *Beijerinckia*, *Burkolderia*, *Microvirga*, *Cupriviadus*, *Mesorhizobium* and *Agrobacterium*. The SNR diversity was higher in grasslands compared to cultivated fields. *Bradyrhizobium* was dominant in cultivated fields (45%) while *Kosakonia* was dominant in grasslands (35%).

The *16s rRNA* phylogeny gave two major clusters divided into five clades whereas the phylogeny based on house-keeping genes (*recA* and *glnII*) divided indigenous rhizobia into three well defined clusters in which only *Bradyrhizobium* (63%) and *Rhizobium* (37%) were presented. The indigenous SNR isolates (NAC55, NAC76, NAC78, NAC47, NAC61 and NAC35) and USDA 110 clustered together with high bootstrap value (84%) suggesting their high degree of relatedness and possibly high economic values of these indigenous SRN isolates in soyabean production.

This study showed that indigenous SNR in South Kivu soils were highly diverse (the computed diversity in the entire population =0.180) and this diversity is even higher in grasslands showing that grassland is an important source of rhizobia. This study showed the presence of promising indigenous rhizobia for improving BNF and soyabean productivity in South Kivu.

This project was supported by the BecA-ILRI Hub through the Africa Biosciences Challenge Fund (ABCF) program. We thank the N2 Africa program for supporting the rhizobia strains collection and maintenance. The Organization for Women in Science for the Developing World (OWSD) is also acknowledged for scholarship grant. The RUFORUM and University of Nairobi are acknowledged for supporting this PhD study.

Ndusha Bintu Nabintu, PhD student University of Nairobi, Kenya. IITA supervisor: Dr. Nabahungu Leon (Click here for her 2018 update)

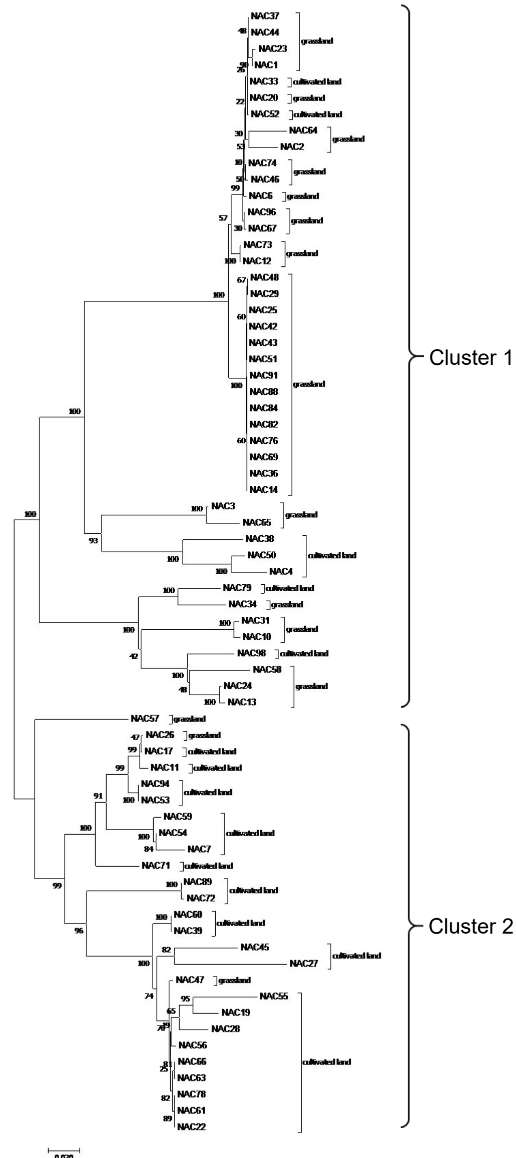

Figure 1: phylogeny of indigenous SNR strains (NAC) collected from grassland and cultivated fields, based on 16S rRNA gene using the Neighbor-Joining method and the Kimura 2-parameter model modelled by a gamma distribution. The bootstrap values (1000 replicates) are shown next to the branches.

Symbiotic interaction between chickpea (*Cicer arietinum* L.) genotypes and Mesorhizobium Strains in Ethiopia

Introduction: Chickpea (*Cicer arietinum* L.) is one of the grain legumes that symbiotically interact with *Mesorhizobium* strains and fix atmospheric N. The efficiency of the symbiotic N fixation partly depends on the host genotype (G_L) and rhizobium strains (G_R). Here, we studied G_L x G_R interaction between genetically determined *Mesorhizobium* strains and chickpea genotypes primarily in jars and subsequently in pots in Ethiopia.

Methodology: chickpea genotypes ($11G_L$) were selected from previously described accessions (Updhayaya, unpublished) based on genetic distances between groups[1] and imported from ICRISAT-India. Five reference strains (reported to nodulate chickpea and vary genetically[2,3], imported from LMG strain collection centre, Belgium) and five phylogenetically characterized local strains following protocols described earlier (see my 2018 update) were selected and studied. Factorial combinations of $11G_L$ x 12 ($10G_R$ + 2 controls (0.05g/ml N fertilized and unfertilized) with 5 replications were tested in jars on sterile sand with RCBD. All treatments were supplemented with Jenson's N-free nutrient solution and assessed for symbiotic effectiveness after 45 days of growth in screening house. Subsequently, $5G_L$ x 8 ($6G_R$ + 2 controls) combinations were tested in pots with similar design as in jars. Nodulation and fixation were measured as nod+/- and fix+/- respectively and visualized to detect patterns (if any) using heatmaps in R version 3.5. Furthermore, symbiotic effectiveness was analysed based on shoot biomass and fixed N using mixed linear models. Combinations with higher symbiotic performance were assessed using additive main effect and multiplicative interaction (AMMI) model in R using *agricolae* package.

Results: Phylogenetic analysis of the reference and local strains, based on 16s rRNA sequences, showed genetic breadth (Fig. 1). However, all the local strains were assigned to *M. plurifarium* (a microsymbiont of *Acacia senegal* L. but sporadically found in chickpea root nodules[4,5]) at lower bootstrap (83%) while the reference strains were evenly distributed in the entire tree. Nodulation and fixation genes grouped the local strains with *M. ciceri* and *M. mediterraneum* (data not shown), reflecting different evolutionary roots in symbiotic and 16s rRNA genes. Heatmaps revealed some patterns in terms of nodulation, fixation and plant shoot biomass (Fig. 2). The distinct and consistent patches indicated widely in the jar and jar subset (the upper three and middle three heatmaps in Fig. 2) were not the real differences observed among the combinations but were due to the missing values in the jar recorded for Kabuli genotypes as a result of weak germination. Besides this problem, weak patterns are observed when only desi genotypes are considered and that is mostly brought about by one strain (*M. ciceri*, LMG14989). This strain was clearly confirmed to be the most effective one across genotypes in the subsequent study in pots (Fig. 2). It fixed the highest amount of N and induced the highest shoot biomass with all the genotypes among the studied strains and was found to be stable across the genotypes.

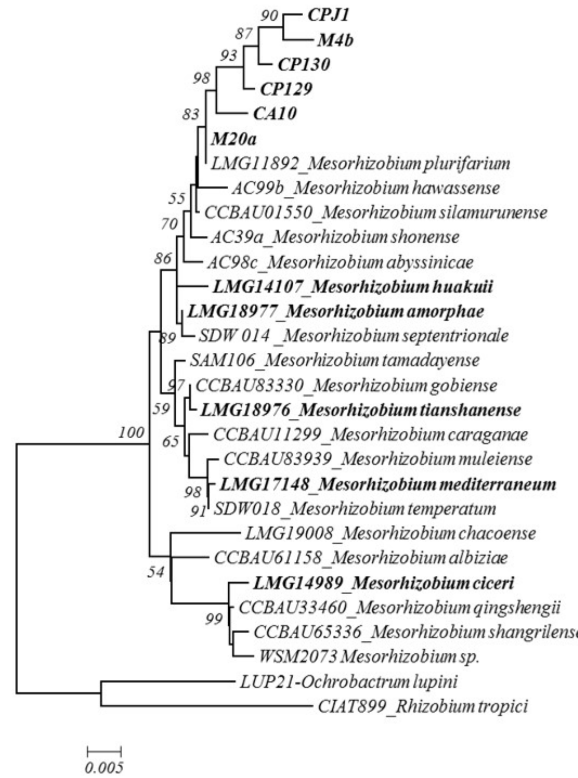

Fig. 1. Neighbour joining 16s rRNA phylogeny of the reference and local strains. Strains labelled in bold are included in this study.

The local strains had weak and similar performance across genotypes, and this is concordant with their similarities reflected in the phylogenetic tree (Fig 1), indicating that they are identical and sporadic symbionts of chickpea that might have obtained symbiotic genes from *M. ciceri* or *M. mediterraneum* strains. Practically, this means that the weakly performing local strains (trapped from different locations) dominate in Ethiopian soils and possibly minimize the potential N_2-fixation by chickpea, as they are not the distinguished chickpea microsymbionts. Besides, we found evidence for the presence of $G_L \times G_R$ interaction in chickpea in jars ($p<0.001$), due to effects of Kabuli genotypes. This evidence was disappeared in the pot experiment (data not shown), in which case excess Kabuli seeds were used to replace the missing ones. Thus, pots can be taken as probable confirmatory supporting media for investigating the presence of $G_L \times G_R$ interaction in legumes. An interesting observation is that strain LMG14989 is a broad genotype spectrum strain that fixes significantly higher N and enhances plant growth.

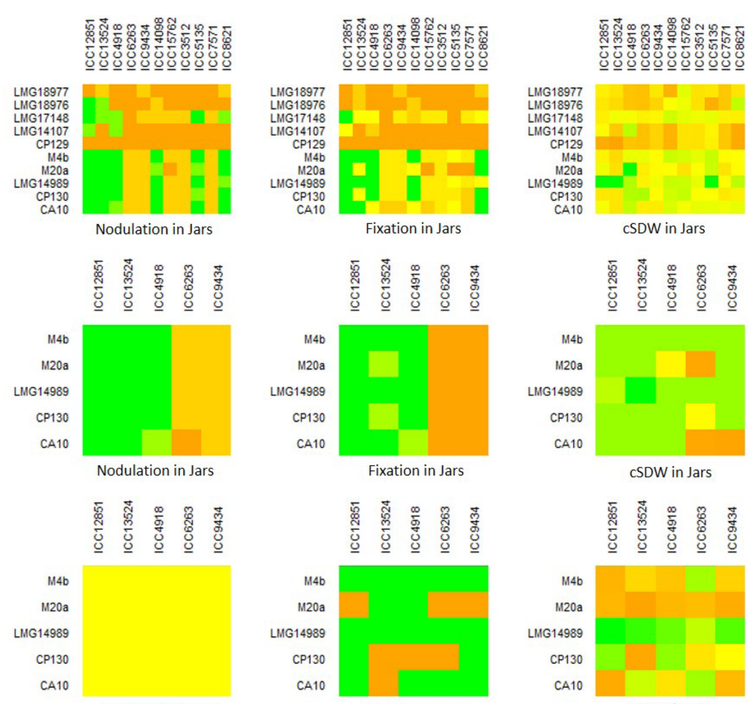

Fig 2. Nodulation, fixation and shoot biomass patterns of $G_L \times G_R$ in chickpea. Where, cSDW is corrected shoot dry weight; Chickpea genotypes are indicated on the x-axis while strains are indicated on the y-axis.

Ashenafi Hailu Gunnabo, Wageningen University & Research, The Netherlands

References:

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Influence of product bundling on farmers' preferences to buy soyabean inputs: A conjoint study in Ethiopia

In my previous year PhD update, I qualitatively explored and highlighted the influence of smallholder farmers' perceptions of legume seeds, inoculant, fertilizer and improved practices on their adoption intentions. As farmers perceive high relative product advantage with the legume inputs, they also perceive low compatibility with prices and packaging of the inputs. Particularly, farmers perceived high uncertainty with market and spray services. Perceived complexity is mainly observed with inoculant application.

Farmer perceptions of product attributes is an indication of the need for the provision of not just legume seeds, inoculant and fertilizer alone but the provision of a combination of legume inputs together with service components so as to enhance adoption or sales. I used a conjoint method and designed options of soyabean input products combining levels of soyabean input attributes identified in my previous study. The soyabean input products were printed on separate cards (see Figure 1 below for sample cards) and given to the farmers to make their preference ratings on 7-point measurement scale ranging from "I would be extremely unsatisfied" to "I would be extremely satisfied".

A total of 252 smallholder farmers who participated on previous N2Africa (www.N2Africa.org) dissemination activity were participated on the interviews. This is because for farmers to give sensible ratings on the soyabean input product offering, prior awareness of the products is important.

The importance values from the conjoint analysis results show that product attributes "Market", "Bundle" and "Brand" have mostly influenced the overall preference ratings with values of 38%, 20% and 11% , as compared to the other attributes (Table 1). For the market service attribute, it means that, about 37% difference in preference between soyabean input products is due to the presence or absence of soyabean grain market contract service. Similarly, 22% of the overall difference in preference is due to whether the offering is just for soyabean seed alone or whether it is a bundle combining of soyabean seed with inoculant or whether it is a combination of soyabean seed along with inoculant and fertilizer. High and positive utility estimates are observed for the product levels that indicate the inclusion of the product attributes in the input offerings.

Table 1 Average importance score of soyabean input product attributes

Importance Values	
Market contract	37%
Bundle of seed, inoculant and fertilizer	22%
Brand	11%
Agrochemical	9%
Information	8%
Small package size	6%
Extra package with bean seed and inoculant	7%

Figure 1: A sample of soyabean input products offered for farmers for rating

Figure 2. Farmers on soyabean input product preference rating task at Bako district.

Large effect size (0.16) for the attribute market service, indicating about 1.6% variance in soyabean input product preferences by farmers and followed by the attribute "Bundle".

The study results imply that input providers can enhance farmers' input purchases through offering a combination of input products and services together. In this respect, we recommend that the private and public actors in the legume sector need to take a different perspective and as such to improve their input products sales performances, they need to bundle it with other necessary inputs or services from other suppliers through, for example, Public-Private Partnerships(PPPs).

In my next study, I will build on the findings of this study and design a field experiment in which representative soyabean input products will be offered to test farmers input purchase behavior.

Tamiru Amanu, International Livestock Research Institute, Ethiopia and Wageningen University & Research, the Netherlands (Click here for his 2018 update)

Allocation of grain legume fodders in mixed crop-livestock systems of northern Ghana

Crop residues are a major feed resource in smallholder mixed crop-livestock (MCL) systems in West Africa. The current decline in grazing land as a result of the ever-increasing population and associated increased demand for land for housing and crop production has further heightened the importance of crop residues as livestock feed. Grain legume residues, also known as grain legume fodders (GLFs) are considered more valuable livestock feed than cereal residues since they have higher digestibility and protein content. Additionally, GLFs is used as fuel, construction material and mulch for soil improvement. The increasing demand for GLFs as livestock feed has implication for the long-term sustainability of MCL systems since failure to return the manure from livestock fed with the GLF to the fields could have a negative impact on soil quality to enhance crop productivity. One of the chapters in my PhD thesis focused on assessing the variation in the allocation of GLF in MCL systems in three regions with different population pressure and agro-ecological conditions in northern Ghana and how these variations impact on the role of GLFs in smallholder mixed crop-livestock systems.

We conducted household surveys in Northern (NR), Upper East (UER) and Upper West (UWR) regions in northern Ghana during the 2016 off-season, from November 2016 to January 2017. A total of 150 households were surveyed from 15 villages, five from one district each in each region (NR – Savelugu district; UER – Binduri; UWR – Nadowli) where the N2Africa Project (www.n2africa.org) was being implemented.

The results show that farmers in the NR and UER use the majority of GLFs as livestock feed, which is stored for stall feeding or through free grazing (Table 1) in the dry season (Plate 1). In UWR, (61%) GLFs is left in the fields as mulch whereas about 30% ever-increasing as livestock feed (17% through open grazing and 12% through stall feeding)

Table 1. Diversity of Grain legume fodder use in MCL systems in northern Ghana in 2017.

Fodder allocation to different use (%)	Northern Region	Upper East Region	Upper West Region
Grazed	26 (3.0)[c]	5 (1.8)[a]	17 (3.3)[b]
Stall feed	43 (3.7)[b]	87 (2.7)[c]	12 (2.9)[a]
Mulched	22 (3.0)[b]	3 (1.4)[a]	61 (4.5)[c]
Burned	8 (1.4)[b]	0 (0.0)[a]	7 (2.7)[b]
Sold	0 (0.0)[a]	1.5 (0.69)[b]	0 (0.0)[a]
Compost	0 (0.0)	1 (0.4)	1 (0.7)
Fuel	1 (0.7)	0 (0.0)	0 (0.4)
Others	0 (0.0)	1 (1.3)	0 (0.0)

Values in the parentheses indicate standard errors (SE). Means in a row with different letter superscripts differ significantly ($P < 0.05$).

Plate 1: Grain legume fodders stored for stall feeding (a) and open grazing (b) in northern Ghana

(Table 1). Less than 10 % of GLFs is burned to ease land preparation in NR and UWR while none of the GLFs is burnt in the UER. The intensified system in UER showed considerable pressure on GLFs as feed with limited surplus for other uses. In the more extensive system observed in UWR showed that the greater proportion of the GLFs were left on the field as mulch for soil amendment. The variation in the use GLFs as feed in northern Ghana had created an intensification gradient in the regions which made UWR less intense followed by NR and UER is the most intensive system.

Some driving factors such as the scarcity of feed from grazing land, number of livestock owned per household, the reason for keeping livestock and distance of crop fields from the homestead could explain these variations in the allocation of GLFs in MCL systems in northern Ghana. The higher usage of GLFs as feed in UER is due to scarcity feed from grazing land and differences in the agro-ecological conditions. Another reason for the higher use of GLFs as feed in UER is that about 80% of the households had cattle which are oxen or bullocks. These animals are major source of draught power for land preparation and carting of food, feed and manure. These animals, therefore, need maintenance feed to survive during the dry season. We also found that in both NR and UWR, crop production is the main source of income, followed by livestock production. In UER, however, income from both crop and livestock production are equally important (data not shown) for the households which made GLFs more valuable.

Based on the above findings we can conclude that there is variation in the allocation of GLFs in MCL system in northern Ghana. This variation in GLFs allocation was caused by the number and type of livestock kept in the household, distant of crop fields to the homestead, land scarcity and population density coupled with high demand for food. This show that livestock production in the smallholder MCL system is likely to continue to depend on GLFs as feed. Therefore there is the need to cultivate dual-purpose varieties of grain legume in tandem with innovations such as rhizobia inoculation and P fertilization to enhance the whole plant value of grain legumes without compromising quantity and quality of GLFs.

Daniel Brain Akakpo, Wageningen University & Research, The Netherlands (Click here for his 2018 update)

Understanding smallholder farming systems in the Guinea savanna of Ghana for targeting grain legume intensification options

In the 2017 N2Africa podcaster, I presented a section of my paper published in Field Crops Research (https://www.sciencedirect.com/science/article/pii/S037842901730727X). My 2018 update provided a brief overview of my paper on legume-maize ecological intensification options published in Experimental Agriculture (https://doi.org/10.1017/S0014479718000273). In this update, I provide a highlight from my last chapter focussed on providing an improved understanding of smallholder farming systems in the Guinea savanna of northern Ghana for targeting of grain legume intensification options.

Smallholder farming systems in the Guinea savanna of northern Ghana are characterised by poor soil fertility and other biophysical and socio-economic resources. These limitations hinder increased and sustained crop productivity needed to feed the growing population. Intensification of grain legume production is important in improving soil fertility, crop productivity, household food and income. However, a better understanding of the pattern of resources allocation, production objectives of farms and how these impact on household food availability and self-sufficiency is needed to target grain legume intensification options in contrasting sites in the Guinea savanna.

The N2Africa Ghana project's baseline data was used for this study. The data is from survey in 2010 in seven districts, 29 villages and 400 farm households, 151 in Northern Region (NR), 129 in Upper West Region (UWR) and 120 in Upper East Region (UER). Here, I only show results for NR and UER. Food availability and self-sufficiency were estimated with per capita (adult equivalent) daily energy requirement of 2210 kcal. Energy content (kcal kg^{-1}) used were cowpea: 3160; groundnut: 5660; soyabean: 4130; maize: 3490; millet: 3480 and sorghum: 3440. Food availability was calculated as the ratio of the total energy produced by farm household to the total energy requirement of the household multiplied by 365 days, assuming all grain produced is consumed in the household. Food self-sufficiency was estimated as the proportion of own food production consumed in the household relative to the total annual energy requirement of the household, excluding the proportion of grain sold or used for sowing. Both indicators excluded food purchased by the households as they sought to measure households' food entitlement from own production.

The results show that 66% of households in NR and 55% in UER are able to meet their annual food requirements assuming all grain produced is consumed in the household (Fig1a, b). However, 20% (NR) and 26% (UER) of households could only meet half or less of their required annual food needs (Fig. 1a, b). Accounting for the proportion of total grain sold or used for sowing (food self-sufficiency) led to a 43% decline in the proportion of households that could meet their annual food requirements in NR and 25% in UER (Fig. 1c, d). Alongside, the proportion of households that were only able to meet only half or less of their required annual food needs increased by 27% in NR (Fig. 1c) and 15% UER (Fig. 1d). The contribution of grain legumes to food requirements of households decreased by 26% (from 38% to 12%) in NR but by 6% (from 49% to 43%) in UER (Fig. 1a – d). These differences reflected the disparity in production objectives of farm households, with farms in NR orienting legume grain for the market and selling over 70% compared with 32% in UER (Fig. 2a, b). Is it worth noting that, farms in NR allocated 29% of the total cropped land to grain legume production compared with only 16% in UER (data not shown). Household size being 37% larger in NR also accounted for the less favourable self-sufficiency situation in NR despite total cereal and legume grain production being about 40% larger in NR (Fig. 2). Thus, production objective and resource allocation pattern of farms should be carefully considered in targeting grain legume intensification options to contrasting regions in the Guinea savanna of Ghana.

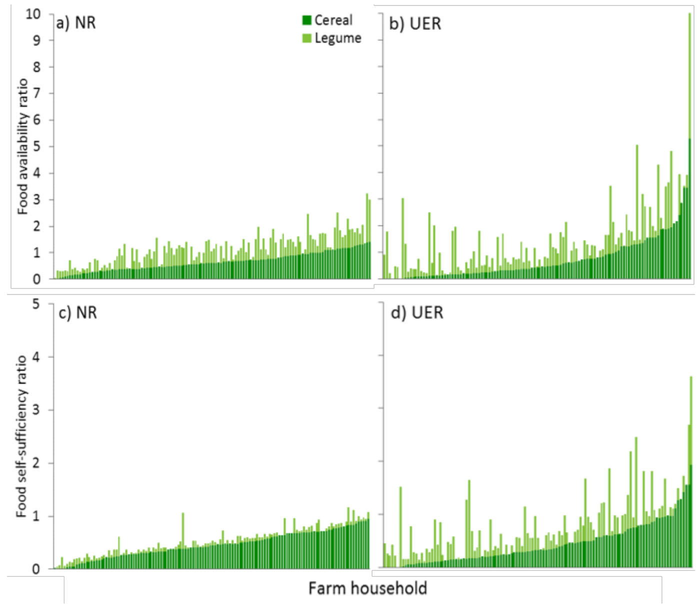


Fig. 1. Food availability and food self-sufficiency of farm households in (a, c) Northern region (NR) and (b, d) Upper East region (UER) of Ghana. Note the different scales for the food availability and self-sufficiency ratios, which was meant to provide better visual appraisal of the bars.

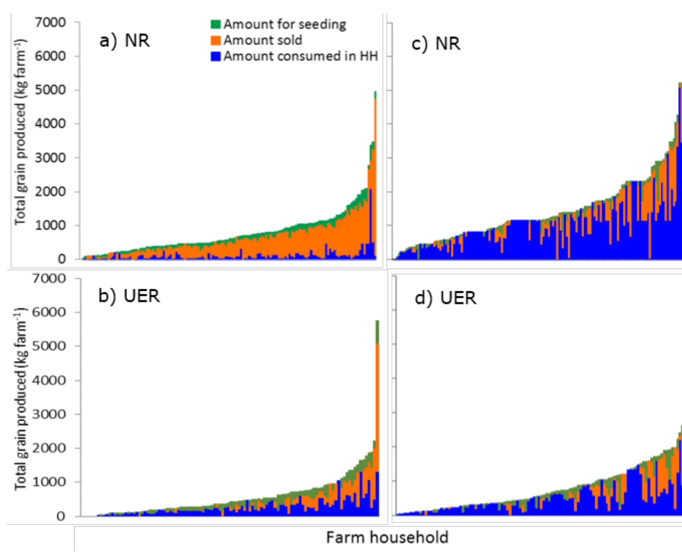


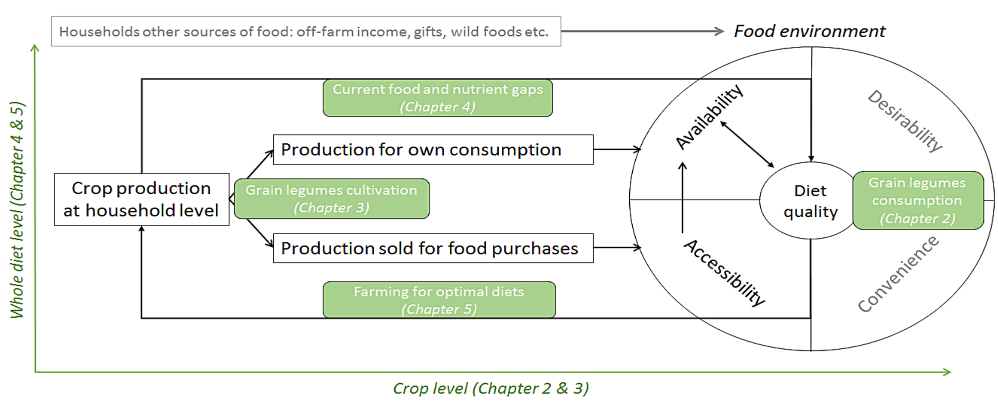
Fig. 2. Production objectives of farm households as indicated by the proportion of total grain production of legumes (a & b) and of cereals (c & d) consumed in the household, sold for income or used for sowing in Northern (NR) and Upper East (UER) regions of Ghana. HH refers to household.

Michael Kermah, Wageningen University & Research, The Netherlands (Click here for his 2018 update)

My PhD results' harvest!

In June I successfully defended my thesis entitled 'Harvesting nutrition. Grain legumes and nutritious diets in sub-Saharan Africa!' What a special day!

The figure on the next page shows an overview of the studies we conducted within a framework based on the theoretical concepts of agriculture and nutrition pathways



Ilse answering the questions of the opponents during her defence, with her paranimphs on the foreground

and the food environment. The main pathways that recur in literature through which agriculture may affect nutrition outcomes are: the production-own consumption and the income-food purchase pathway. The food environment links agricultural production and income on the one hand with consumption on the other hand. The food environment is defined as the availability, affordability, convenience and desirability of various foods that affects people's food choices and therefore diet quality. My PhD research focussed on the food availability and affordability in the food environment, as agricultural production of rural households will most directly affect these two elements. The framework was studied at two levels: (1) *at crop level*, addressing the potential role of grain legumes in relation to diet quality (Chapter 2) and the potential of grain legumes production of households and nutrition outcomes (Chapter 3) and (2) *at whole diet level*, using a systems approach, investigating on the one hand the current contribution of the crop production in a household to high quality diets (Chapter 4) and on the other hand the optimal combination of crop production to ensure a high quality diet in all seasons (Chapter 5). Our main findings include:

1. The main contribution of legumes to nutritious diets is in terms of micronutrients intake and not protein intake.
2. A project promoting grain legume cultivation will not necessarily result in dietary improvements but depend on the food environment, whether a nutrition-specific goal is set and activities such as nutrition behaviour change communication and women's empowerment are included.
3. A mixed method design including pathway analysis is a good approach to study nutrition impact of agriculture interventions when RCTs are not possible.
4. Investigating the gaps in food availability and food needs for nutritious diets using a systems approach provides useful insights to be able to better coordinate and integrate nutrition across agricultural interventions and investments.

My thesis will be publicly available via the Wageningen University Library site from half June 2020.

Thank you all for making this a great project to work in!

Ilse de Jager, Wageningen University & Research, The Netherlands (Click here for her 2018 update)

Sharing project benefits

Last June, a small case study was done in northern Ghana to investigate how farmers perceived their interactions with N2Africa. Any agricultural development project – N2Africa included – can work with only a limited number of people. This means that some people within a community may benefit more than others. Farmers indeed recognized this. See the two text blocks on the right hand side:

Us:	"Why were you interested [in joining N2Africa activities]?"
Respondent:	"I want to be the first one to try. It [the training] will only benefit those who immediately try."
Us:	"Why do the first benefit most?"
Respondent:	"They benefit most. 'First come, first serve'. The first will receive proper training. If the trainers come back later, the training may be partly or fully skipped."
Respondent:	"Do you think it was like this with N2Africa?"
Respondent:	"Yes, those ten who were involved in the demo understand the technologies best."

Us:	"Do you think that some people benefit more from N2Africa than others?"
Respondent:	"Yes, but not so much. Those who are involved will tell if you ask. They will not go and share actively, but you can ask. Those who benefit most from the technologies are those who are most serious: they pay attention and apply technologies correctly."

We then organised a group discussion with about this topic. We put the 40 participants into the shoes of the management team of a hypothetical agricultural project. This project arrives in a community of 12 people and has a total of 9 Ghanaian cedi to spend on training about agricultural practices. The project management can choose between three alternative project strategies (illustrated in Figure 1):

1. Spend 1 cedi per person and give 9 people training. With this training, those beneficiaries generate 1 extra bag of crop produce.
2. Spend 1.5 cedi per person and give 6 people a more elaborate training. With this training, those beneficiaries generate 2 extra bags of crop produce.
3. Spend 3 cedi per person and give 3 people the full training. With this training, those beneficiaries generate a lot of extra crop produce, equivalent to approximately 5 bags.

In lively discussions the participants discussed the different project strategies and after 10 minutes a spokesperson explained their preference.

Each group counted how much extra produce was generated in each of the scenarios. The first group of women chose strategy 3, because the total output was largest. The people who were trained would share their knowledge and their extra output with the others. The second group of women chose for strategy 2 and they explained that if half of the community is trained, those people can easily share information and their extra produce with the other members of the community. The group of men reasoned similarly and chose strategy 2 as well.

Strategy 1 was disliked because the total quantity of extra produce is smallest, and the quantities in strategies 2 and 3 are larger and shareable.

Each group assumed that trained persons would share new information and their extra crop produce with others. We asked plenary whether this happens in reality.

> Participant: "If someone would get a package, there is no rule about harvest sharing, but it is embodied in the group to help each other either with info or with produce."

Of the men who were present, all men (7) except one had received the training from N2africa. From the 33 women only

Focus group discussion in northern Ghana, June 2019

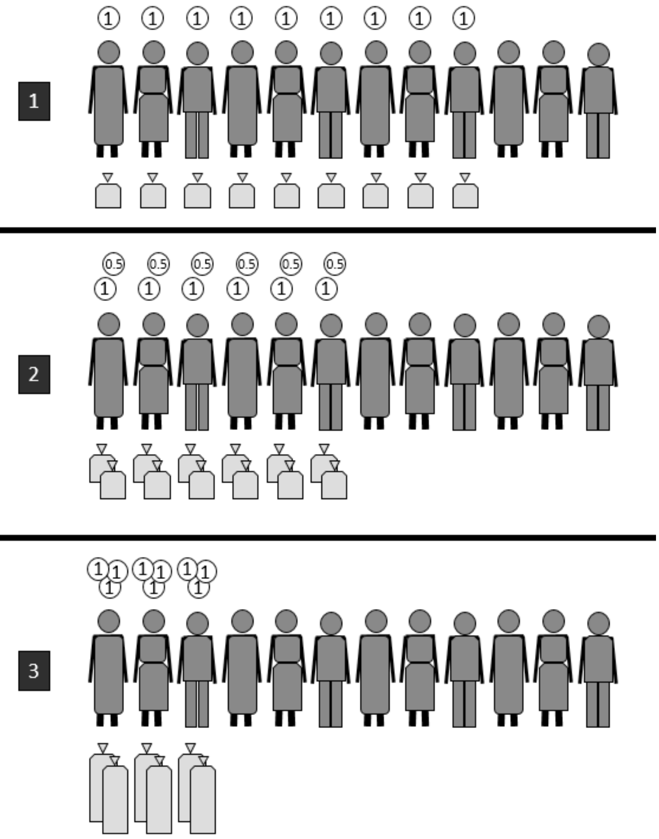


Figure 1. Three project strategies for investing a budget in training individuals. Coins: money invested in giving that person training on improved agricultural practices. Bags: extra produce generated by that person as a result of the training. More (intensive) training means a larger yield output.

2 had received the training. We asked whether those persons that had not received the training from N2Africa directly, has still received or learned something. Hands were raised by 11 women who claimed that they had learned about the recommended practices. When the members of the 'N2Africa group' were receiving the training at the demonstration trial, these women were also there to observe and help out, or they would hear about it from neighbours or at gatherings.

We then reasoned that it may be necessary for a farmer to fully sell his or her improved crop output to be able to save and generate the same output in the next season. If that person shares the output, he or she may not be able to do the same next year. People had not looked at the strategies like that, but there was no room anymore for going into further detail and discuss it in plenary. The translator noticed that the participants were discussing it enthusiastically as we wrapped up. It was a fun game and worth some further playing!

Eva Thuijsman, Wageningen University & Research, The Netherlands, gratefully acknowledging Harmen den Braber, Peter Anyagri and Rasheed Imoro.

Diverse Bradyrhizobia strains can nodulate cowpea in Nigerian soils

Cowpea is an important grain legume valued for its N_2-fixing ability and nutritional attributes of its grain and leaves. The symbiotic relationship of cowpea with its microsymbiont rhizobia do account for 96% of its N requirement, can as well contribute to the N needs of subsequent cereal crops in Sub-Saharan Africa, where soils are nutrient-poor. Several studies has indicated that Bradyrhizobium and Rhizobium are the microsymbiont that nodulate cowpea but much remains to be known about the diversity of the naturally occuring rhizobia strains in the major growing cowpea regions in Nigeria. The result explained in this write up show the analysis of the multilocus sequence analysis of 16srRNA in combination with housekeeping gene.

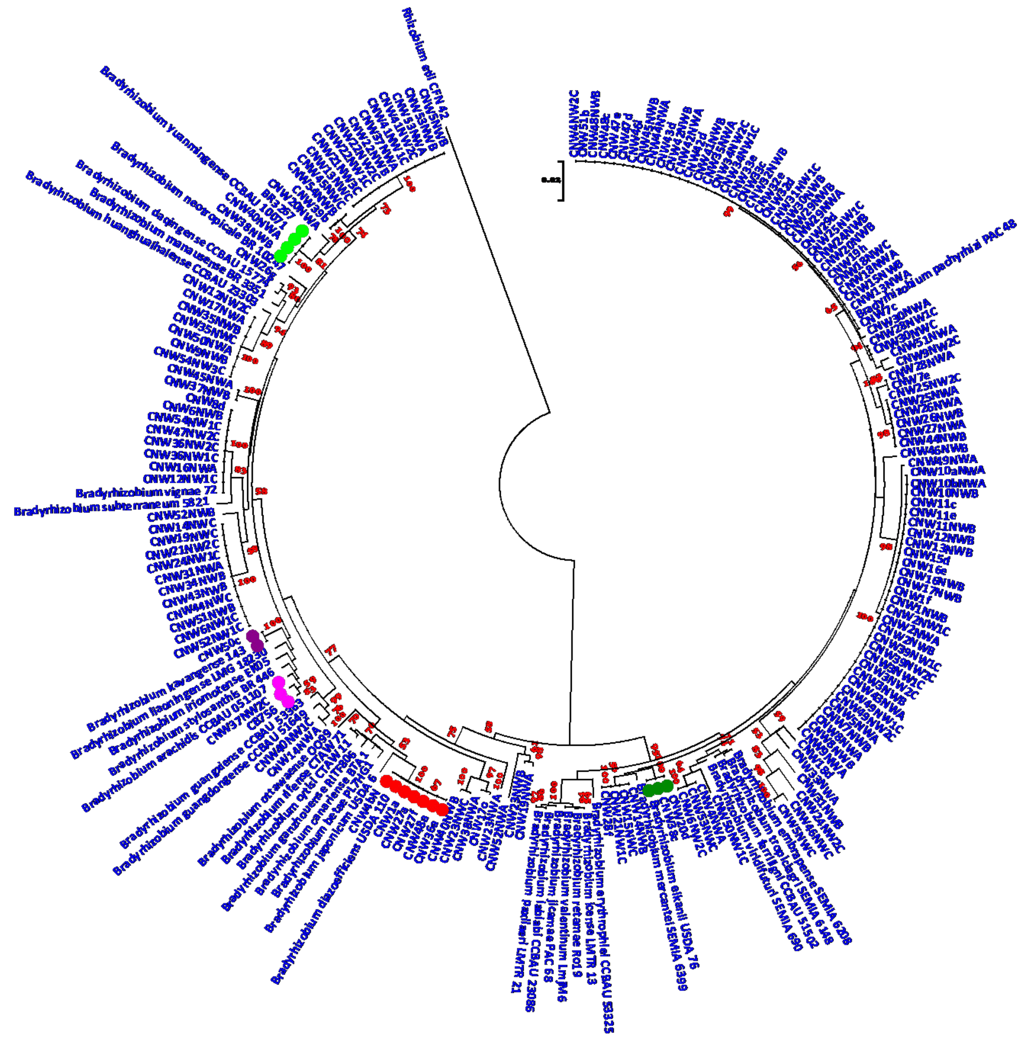


Figure 1. Maximum likelihood phylogeny of cowpea nodulating rhizobia from Nigeria based on concatenated sequences of *16SrRNA-glnII-gyrB-recA* genes

Soil samples were collected from 54 different farm field in three cowpea growing region in Nigeria (Niger, Kaduna, and Kano). Three rhizobia strains were isolated from each soil samples making a total of 162 strains isolated. The strains were subsequently authenticated in further experiment using cowpea cultivar IT97K-499-35 as the trap host to ascertain whether these strains can renodulate cowpea. Subsequently the strains were further amplified via a direct colony polymerase chain reaction using primer pairs for 16S, gyrB, glnII and RecA gene. The purified DNA was sequenced and further phylogenetic analysis were carried out using MEGA 7 software. The multilocus sequence analysis of recA, glnII, gyrB and 16S rRNA were reconstructed using the maximum likelihood method using Kimura's 2-parameter model. Genospecies were defined based on the MLSA relationship using a 97% sequence similarity threshold.

The isolates shown in Figure 1 clustered with *B. elkanii*, *B. daqingense*, *B. kavangense*, *B. yuanmingense* and *B. diazoefficiens* which is indicative of what other studies show. Isolates labelled with red all cluster with *B diazoefficiens* USDA 110 with 100 % sequence identity. Furthermore, our results also showed that isolate CNW26g clustered with *B. daqingense* (pink label), a strain originally isolated from soyabean nodules in China and subsequently found to induce effective nodulation on cowpea. The presence of *B. daqingense* in African soils could be caused by its introduction with soyabean seeds from China. Isolates CNW20d, CNW38c clustered with the *B. elkanii* group with 100% sequence identity. The 162 rhizobia isolated from cowpea in the three growing regions showed great diversity and biogeographical patterns.

Ojo Comfort Tinuade, Wageningen University & Research, The Netherlands (Click here for her 2018 update)

Responses of cowpea (*Vigna unguiculata* L. Walp) varieties to rhizobia inoculation, phosphorus application and sequential cropping system in Minna, Nigeria

My study aimed to exploit rhizobia inoculation, phosphorus application, varietal differences and sequential cropping system to improve the productivity and profitability of cowpea per unit area in Minna, Nigeria. Glasshouse and field experiments were conducted between 2015 and 2017. The treatments evaluated during the study were: five rhizobial strains (USDA 3451, USDA 3384, BR 3262, BR 3267, control), three phosphorus rates (0, 20 and 40 kg P ha^{-1}), six varieties of cowpea and soils were collected from 20 locations in Nigerian savannas. Data were collected on growth, nodulation, yield and physiological parameters.

Summarily, results revealed that the cowpea varieties successfully formed symbiosis with the introduced rhizobia strains in all the locations. Rhizobia inoculation increased nodulation in 11 out of the 20 locations with percentage increase ranging from 4 to 43%. Plants fertilized with 90 kg N ha^{-1} had significantly ($P \leq 0.05$) higher biomass yield than the inoculated and uninoculated plants which had similar biomass yield; suggesting the need to test more effective cowpea inoculants in Nigerian savannas. Rhizobia inoculation significantly ($P \leq 0.05$) increased the seed protein content of the cowpea varieties. Phosphorus significantly ($P \leq 0.05$) increased the photosynthetic activities, nodulation, N-fixation, growth and yield of the cowpea varieties in the three years with application of 20 kg P ha^{-1} increasing grain yield by 49-95% over the control. Crop growth rate (CGR), leaf area index (LAI) and quantum yield of photosystem II (Phi 2) explained 67.29% of the variation in grain yield (R^2= 67.29%). The six varieties tested were successfully planted in two sequence in each growing season except Kanannado. IT93K-452-1, IT99K-573-1-1, TVX-3236 and IT90K-76 varieties had significantly higher ($P \leq 0.05$) grain yield and higher profitability than Oloyin and Kanannado varieties which were produced at a loss in the first planting. Planting these four varieties in sequential cropping system increased the profitability by 157-236% than the traditional practice of planting once in a season.

My thesis write-up is completed and I have presented my internal exit defense. I am awaiting the external defense which will come up shortly. The results of the experiments were presented in World Cowpea Conference 2016, International Association of Research Scholars and Fellows symposium 2017 and 2018, International Conference of Agriculture and Agricultural Technology, 2018, Association of Seed Scientists' of Nigeria Annual Conference, 2019. Some of the results were also published in Production Agriculture and Technology Journal, 2018; 14(2): 131-139. I am awaiting publications from other journals.

Adediran Olaotan Abimbola, Federal University of Technology, Minna, Nigeria (Click here for her 2018 update)

Enhancing biological nitrogen fixation and yield of soyabean and common bean in smallholder farming systems of Rwanda

Climbing bean is a very important crop in Rwanda especially in the highlands of the Northern Province. However, yields achieved by farmers in the area remain low. This is due to overexploitation of the tiny lands with little or no fertilizer use. A field experiment was established in Kinoni and Muko villages of the Northern Province to identify which nutrients are limiting in climbing, using the Compositional Nutrient Diagnosis (CND) and the Diagnosis and Recommendation Integrated System (DRIS). Climbing bean leaf samples were collected in 56 plots from experimental fields. The 56 samples were collected in treatments with no inputs, with full NPK, with NPK + manure, and with manure only selected from a set of 210 plots, and were analyzed for N, P, K, Ca, Mg, Cu, Mn and Zn. DRIS and CND approaches were applied to rank nutrients according to their degree of limitation to climbing bean. Results suggested that Zn was the most limiting nutrient at both sites. In Kinoni Zn was the most limiting, followed by N, K and P; while in Muko Zn was the most limiting, followed by Mg, Ca, P and N as shown in Figure 1 below. This suggests that improvement of soil fertility in Northern Rwanda may target the use of micronutrients in addition to N, P and K, and development of site-specific fertilizer recommendations instead of blanket recommendations. On-farm crop response experiments are needed to confirm whether these nutrients are truly limiting crop production in the field.

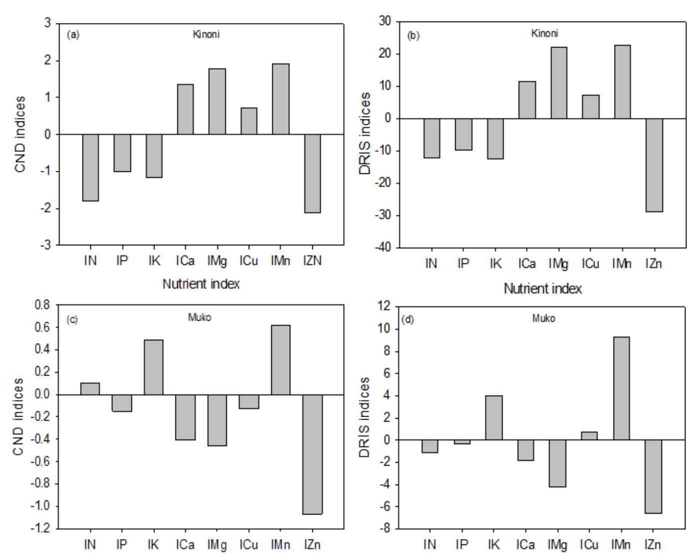


Figure 1. CND (a, c) and DRIS (b, d) nutrient index values for leaf tissue at Kinoni (a, b) and Muko (c, d) sites.

Edouard Rurangwa, Rwanda Agriculture and Animal Resources Development Board (RAB), Rwanda and Wageningen University, The Netherlands (Click here for his 2018 update)

The Role of the Integrated Maize-Soyabean-Chicken Value Chains in Sustaining Diverse Diets: the case of Southern Highlands of Tanzania

Six months after his MSc Animal Sciences, Wilson Charles returned to Wageningen University in April 2018 for a PhD program while registered at Plant Production Systems group. Primarily, he joined N2Africa and The Missing Middle project where his research focuses on exploring the role of the current soyabean-chicken-maize value chains in sustaining diverse diets in the Southern Highlands of Tanzania. The focus was on these value chain(s) since integrating soyabeans in the integrated maize-chicken value chains might improve soil fertility and subsequent maize yield through Nitrogen fixation and increase the productivity of chickens by providing nutrient-dense feed. These chickens are needed to meet the growing demand for eggs and meat in the country.

The current research involved a scoping study followed by an in-depth literature review and interviews using semi-structured questionnaires to understand chicken farming typology whereby 121 poultry keepers were interviewed in three districts of Iringa region. Furthermore, we carried out a multi-stakeholder workshop with 54 stakeholders and experts involved in the development of the maize, soyabean and chicken value chain(s) to identify important points for value chain integration, to support nutritious diets in the region.

Three systems of poultry keeping were identified in the study area i.e. extensive, semi-intensive and intensive systems, with diverse feeding strategies ranging from scavenging, home-made ration, industrial feed and combination of home-made and industrial rations. Poultry feeds processed by local industry is either supplied to large scale chicken farmers or to the agents who supply to the smallholders, mid-scale farmers and brooders. The informal chicken market (for eggs, live/slaughtered chickens) dominates both urban and rural location.

The current maize, soyabean and chicken value chains inter-connected particularly at the levels of the smallholder farming system and at processing facilities. The production of one or more of these products contribute to farmers' food security and income. Poultry feed is an important entry point for integrating the three value chains, whereby maize (grain/bran) and soyabean meal could serve as the main sources of energy and protein for chicken, respectively. Currently, crop farmers play important roles in supplying feed ingredients to the grain market, feed-ingredient suppliers, feed processors, hatcheries and chicken farmers, mainly through middlemen. A small proportion of maize produced is exported to neighbouring countries, while the current amount of soyabean produced is mainly marketed in the domestic market.

Although the introduction of soyabeans is promising, the locally produced grains are underutilized due to inefficient marketing and processing in the country, mainly due to disorganised producer groups and lack of adequate processing plants. As a result, soyabean meal is mainly imported and sold at almost three times higher prices than the whole soyabean grain produced in the country. Improving soyabean marketing and investment in processing infrastructures has a great potential in promoting soyabean production and ultimately contribute to increasing local availability of soyabean meal (as well as oil and flour). Improving availability of locally produced soyabean meal might reduce the cost of feed-in chicken farming and consequently promoting the production of chicken eggs and meat to meet the increasing demand of chicken meat and eggs for urban and rural consumers.

Figure 1. A participatory workshop on value chain mapping and stakeholders analysis in Iringa region.

In the next step, we will further assess the quality of chicken feed and feed ingredients and exploring different feeding strategies in Tanzania. More specific, we will explore the alternative protein sources that would supplement fish meal in poultry feed formulation which is currently scarce. A better understanding of feed quality and feeding strategies is expected to reveal the gaps hindering chicken productivity and exploring the opportunities for the utilization of soyabean as a supplement of fish meal in a view of food-feed competition.

Wilson Charles Wilson, Wageningen University & Research, The Netherlands (No previous updates)

Legume Technologies’ adoption among smallholders: Role of ICT market interventions and impact

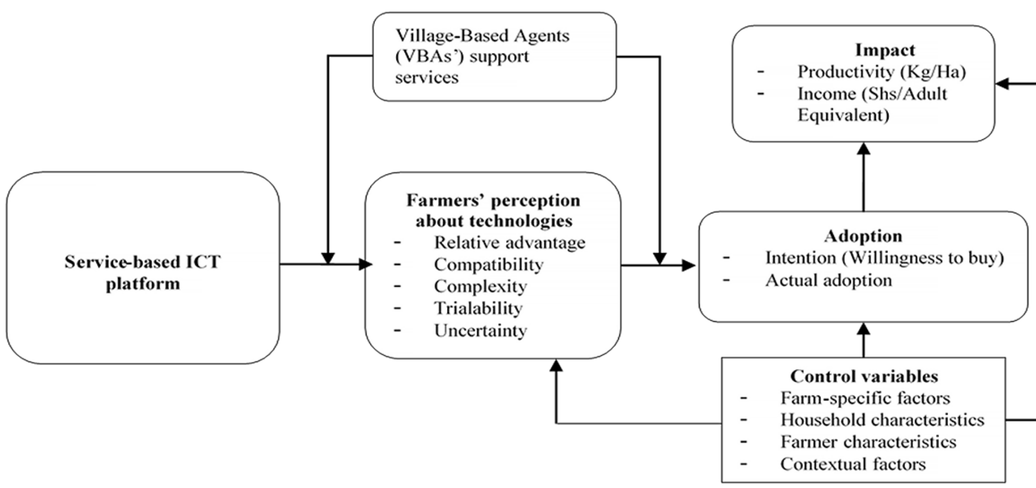
African farmers are increasingly presented with innovative technologies to maximise their agricultural production potential and remain food secure. One of the innovations has been through the biological nitrogen fixation project N2Africa promoting proven legume technology packages (Improved seed varieties, phosphorus fertilisers, inoculants for improved productivity. Whereas considerable efforts have been made, adoption remains low due to limited knowledge and information on available technologies, inputs, credit and other services. The rapid growth of ICTs presents an opportunity to overcome information related deficiencies in agriculture (Nakasone et al., 2014). However, the existing ICT initiatives have tended to offer disaggregated services to address specific challenges such as; extension, inputs, market intelligence, among others, without consideration for bundled services as required by farmers who continue to face a myriad of information gaps across the value-chains. While there is evidence on the role of ICTs in information exchange, there is a knowledge gap on how a service based ICT platform enhances adoption of technologies and whether this leads to productivity and income increase for smallholders.

Methodology:

1. Multiple case study on various ICT interventions and their influences on smallholders adoption.
2. Field experiment to test the service-based ICT Platform on smallholder’ Adoption of legume technologies

Expected results:

1. A theoretical framework on how ICT platforms can strengthen smallholders’ adoption of farming technologies.
2. A service based ICT platform providing bundled services to all actors.
3. Effect of ICT platforms on legume technologies adoption.



Connetie Ayesiga, Wageningen University & Research, The Netherlands and IITA, Kampala, Uganda. Her research locations are two legume growing districts: Apac and Oyam in Northern Uganda. (No previous updates)

Genetic diversity and symbiotic efficiency of indigenous and naturalised soyabean root nodule from Zimbabwe

I carried out glasshouse and laboratory work at Murdoch University, with Zimbabwean isolates of soyabean root nodule bacteria that I collected from soils with a history of inoculation in Zimbabwe. I worked with a total of 137 soyabean root nodule bacteria isolates that were revealed by molecular methods to be drawn from the four species, *Bradyrhizobium diazoefficiens*, *B. elkanii*, *B. japonicum* and *B. ottawaense*. Although sites had been inoculated with *B. diazoefficiens*, they were dominated by the indigenous *B. elkanii.* Indigenous rhizobia are expected to exhibit greater environmental fitness in Zimbabwean soils than the exotic strains.

In 2015, I returned to full time employment in Zimbabwe where I work at the Soil Productivity Research Laboratory, involved with rhizobia inoculant production and promotion, soil testing and fertilizer recommendations, and integrated soil fertility management research. In 2016-2017, I selected the best two isolates from each of the four *Bradyrhizobium* species identified in glasshouse work at Murdoch as potential inoculant candidates and assessed their capacity for elite nitrogen fixation under field conditions at three sites in Zimbabwe. Results show that the best strains from each of the four species elicit high nitrogen fixation with a broad range (three) of commercial soyabean varieties available in Zimbabwe. We found that indigenous rhizobia, particularly *B. elkanii* were superior to the inoculant strains with respect to nodulation under field conditions. Based on biomass accumulation and nitrogen uptake, we recommend strains from the *B. japonicum* and *B. diazoefficiens* species for use in inoculant production.

I have previously reported on all this work and I am now working on publishing my research in peer-reviewed journals and submitting the thesis for examination.

Mazvita Chiduwa, Murdoch University, Australia, supervised by Julie Ardley, John Howieson, Paul Mapfumo, Graham O'Hara and Ravi Tiwari

Overview of students that, to date, completed their PhD

- George Mwenda: Characterization of nitrogen-fixing bacteria from *Phaseolus vulgaris* L. in Kenya;
- Amaral Machaculeha Chibeba: Characterization of rhizobia isolated from soybean in Mozambique and strategies to maximize the contribution of biological nitrogen fixation;
- Eskender Andualem Beza: Citizen science and remote sensing for crop yield gap analysis;
- Mesfin Dejene Ejigu: Options for improving the yield and nutritive value of maize and grain legume residues for ruminants in East African farming systems;
- Binta Ali Zongoma: Impact Assessment of Improved Cowpea Varieties on Women Farmers in Southern Borno State, Nigeria;
- Esther Ronner: From Targeting to Tailoring - Baskets of options for legume cultivation among African smallholders;
- Kehinde Dele Tolorunse: Phenotyping and yield stability studies in soybean (*Glycine max* (L.) Merrill) under rhizobia inoculation in the savanna region of Nigeria;
- Daniel van Vugt: Participatory approaches to diversification and intensification of crop production on smallholder farms in Malawi (No link available yet);
- Ilse de Jager: Harvesting nutrition. Grain legumes and nutritious diets in sub-Saharan Africa (No link available yet).

N2Africa publications

Nodulation, Nitrogen Fixation and Productivity of Cowpea (Vigna unguiculata) Varieties as Influenced by Rhizobial Inoculation and Phosphorus Application on Farmers' Fields in Minna, Southern Guinea Savanna of Nigeria. 2018 by O.A. Adediran, A. O. Osunde, A. Bala, M. Dianda, H. Ibrahim, O. O. Olufajo and J. A. Oladiran.

Reports and other output uploaded on the N2Africa website

- Responses to inoculation of Phaseolus beans on N2Africa trials in Ethiopia, Tanzania, Rwanda and Zimbabwe.

Related newsletters

- SeedSystems blog: Institutionalizing Quality Declared Seed (QDS) Systems in Uganda;
- Icrisat news: First ever high-yielding chickpea variety developed using marker-assisted backcrossing (MABC) released in Ethiopia;
- Tropical Grasslands: Forages for the future newsletter 9

Announcements

We are pleased to announce the re-launch of Feeding a Hungry Planet: Agriculture, Nutrition and Sustainability!

This new run of Feeding a Hungry Planet will launch on 9 September 2019 as a year-long self-paced course.

Learners can join at any time and access all the material at once, completing the course in its entirety or choosing the content that is most relevant to them. Enrollment is open now.

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