N2Africa: Final Report of the First Phase

2009-2013

Paul Woomer, Jeroen Huising, Ken Giller

With contributions from: Freddy Baijukya, Speciose Kantengwa, Bernard Vanlauwe, Steven Boahen, Judith de Wolf, Linus Franke, Robert Abaidoo, Mahamadi Dianda, Jean Marie Sanginga, Esther Ronner, Greta van den Brand and Charlotte Schilt

N2Africa

Putting nitrogen fixation to work for smallholder farmers in Africa

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Email: n2africa.office@wur.nl
Internet: www.N2Africa.org

Authors of this report and contact details

Name: Paul Woomer
Address: CIAT-Kenya
E-mail: plwoomer@gmail.com

Name: Jeroen Huising
Address: CIAT-Kenya
E-mail: j.huising@cgiar.org

Name: Ken Giller
Address: Wageningen UR, Plant Production Systems, P.O. Box 430, 6700 AK Wageningen, The Netherlands
E-mail: ken.giller@wur.nl

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Foreword

We are delighted to introduce this report of the first phase of N2Africa. Over the past four and a half years N2Africa has worked in eleven countries of sub-Saharan Africa. Looking back it has been an extremely rewarding and enriching experience. None of what N2Africa has achieved in terms of learning, impacts and outcomes would have been possible without the enthusiasm and active partnership of the farmers and a myriad of other farmer organizations, the local and international NGOs, national and international research and extension, universities and private partners – the list could be much longer. We thank all of our partners and recognize their key contributions.

In addition to the authors of this report, some individuals played key roles. First of all we thank Prem Warrior of the Bill & Melinda Gates Foundation whose vision and commitment was instrumental in the initial conceptualization of N2Africa and moving from proposal to funding and implementation. As Prem moved on to other responsibilities we were grateful to Charlene McKoin and Vipula Shukla who took over the reins and helped enormously with developing the new focus for a second phase of the project. Kenton Dashiell and later Jeroen Huising, with some interim support from Alastair Simmons, coordinated the project from Nairobi across many countries which was essential to the success of the project. We thank the N2Africa Steering Committee for all their inputs: Anne Mbaabu, Alliance of Green Revolution in Africa (AGRA) who gave us great input on linking to markets and value chains, Ramadjita Tabo, Forum for Agricultural Research in Africa (FARA) who helped to keep national partnerships in the limelight and on agronomy, Mariangela Hungria of EMBRAPA, Brazil and John Howieson of the Centre for Rhizobium Studies, Murdoch University, Australia for their passion and enthusiasm for rhizobiology, Louise Sterling, independent consultant for her insights and guidance on seed systems and on monitoring and evaluation, Nteranya Sanginga and later Deborah Bossio on behalf of TSBF, CIAT and Pamela Bramel and later Nteranya Sanginga for IITA. Although Nteranya Sanginga's roles changed from co-writing the proposal to being Director General of IITA, he remained one of N2Africa's most strident advocates. John Lynam conducted an external review of N2Africa for the foundation and provided much wise counsel.

In each of the countries, N2Africa had a large team of field liaison officers, administrative and finance officers, PhD and MSc students who contributed enormously. More behind the scenes, the complex issues of financial reporting were supported by Lenie Kooijman, Kayode Awobajo, Hilde Koper, Beatrice Nyaboke and Wanjiku Kiragu. Lorraine Odhiambo provided administrative support in Nairobi and Charlotte Schilt in Wageningen. Marcel Lubbers supported our data management systems and the N2Africa website. Many thanks to Charlotte for her excellent publication skills demonstrated in the Podcasters and the many reports.

In highlighting specific people we run the risk of missing others who have contributed and we apologise if that is the case. Although this report is more than 100 pages it cannot cover everything and there are many other documents listed at the back that provide further information. We hope you will find the report of interest and welcome any feedback you may have.

Ken Giller & Bernard Vanlauwe

ken.giller@wur.nl - b.vanlauwe@cgiar.org

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1 N2Africa Highlights

The charitable purpose of N2Africa is to increase the inputs of atmospheric nitrogen from biological nitrogen fixation (BNF) through grain legumes, thereby improving crop and livestock productivity, human nutrition and farm income, while enhancing soil health. This is achieved through uptake of state-of-the-art legume and rhizobial inoculant technologies by African smallholder farmers. It is based upon the recognition that agricultural production in most parts of sub-Saharan Africa is dominated by smallholder farming systems of poor productivity, often due to a deficiency in the supply of nitrogen (Section 2, Franke and de Wolf 2011). Grain legumes have the potential to improve system productivity, yet they are often minor intercrops compared with cereals, roots or tubers. Several highlights from N2Africa are summarized below.

The Development to Research approach

As opposed to the dominant 'agricultural research for development' (AR4D) paradigm, N2Africa focuses on the delivery and dissemination (D&D) of the best available N2- fixing legume technologies at the core of project activities (Figure 1.1). Monitoring and evaluation (M&E) seek to understand why certain technologies work best for particular farmers, and feedback loops through adaptive research seek to refine and improve the technologies through addressing those problems that emerge. Thus, the emphasis is on improving N_2-fixing legume technologies through learning loops, solving problems encountered in the field, understanding how to tailor technologies to different farms and farming systems and using this understanding to refine D&D. Thus we focus on continuous improvement in those technologies and their availability and application at the farm level (Baijukya and Vanlauwe 2011). This approach is unique. as it does not rely upon the creation of new technologies following lengthy Research and Development, rather it takes what is available and improves upon it. Different countries and farming communities vary in terms of their practical understanding of N_2-fixation as a farm resource and access to the technologies advancing grain legume enterprise, and the Development-to-Research paradigm allowed the project to put N_2-fixation to work for smallholder farmers in Africa across very different agro-ecological and socio-economic settings. N2Africa relied upon participatory activities and both formal and informal monitoring and evaluation mechanisms, culminating in a comprehensive Early Impact Assessment that quantified project gains among its many clients and partners.

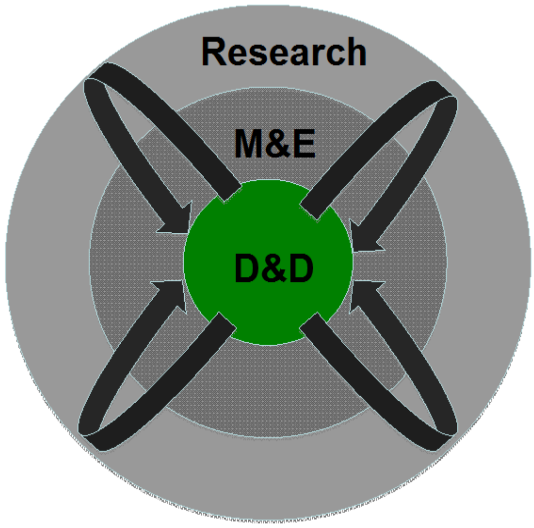


Figure 1.1: The Development-to-Research operations model where technology dissemination delivery serves as the core objective, monitoring and evaluation provides learning and research analyses feeds back into technology design and application.

Box 1.1: A conceptual model that applied advances research into increasing biological nitrogen fixation among Africa's smallholder farmers.

$(G_L \times G_R) \times E \times M$ where:

G_L = legume genotype

G_R = rhizobial strain

E = environment

(GL × GR) × E × M

Project achievements include proof of concept of the $(G_L \times G_R) \times E \times M$ model (Box 1.1), demonstrating that an integrated approach is needed to close legume yield gaps and secure residual benefits from N_2-fixation. Basically, this equation states that the amount of yield and N_2-fixation attainable from a farming system is a function of the genetic potential of its legumes (G_L) and rhizobia (G_R) as conditioned by its environmental conditions (E) including soil and weather and ensured through improved agronomic management (M). This model framed our research in legume agronomy and rhizobiology in a manner that evaluated current smallholder varieties and management and provided sets of locally adjusted "best fits" (Turner and de Wolf 2012). N2Africa's quantitative targets were then approached through the effective dissemination of these BNF and accompanying technologies, and their incorporation of local agricultural development agendas. While intervention and partnership strategies varied among countries, the model guided different research teams using similar approaches.

Best practice adjusted to local conditions

Widespread testing of "best-bet" legume technologies offer practical solutions but also reveals huge variability in performance in farmers' fields. N2Africa has invested substantially in identifying the best grain legume varieties and appropriate management practices for integration into African farming systems. Variety trials were conducted to acquire promising varieties of bean, cowpea, groundnut and soyabean, comparing them to current lines for yield, N_2-fixing capacity and adaptation to abiotic and biotic stresses (Baijukya et al. 2013). In total 266 varietal tests were conducted across the project. From these trials, 26 superior varieties of grain legumes were identified. Seven varieties of soyabean offer great promise on the basis is of their agronomic traits and farmer and market acceptance, five from existing varieties and two new ones. Six bean varieties were identified for East and Central Africa, four climbing varieties and two bush types based upon their seed characteristics and resistance to pest and disease. Six cowpea varieties were recommended, three each for Southern and West Africa, and seven groundnut varieties were best, four in Southern Africa and three in West Africa (Section 4).

Accessing the best varieties, acquiring quality inoculants and identifying initial fertilizer sources and rates served as the initial basis for technology testing. Yield increase following P application was recorded across the Impact Zones in 60% of trials, with yield increase of 5-50% depending on P-source, type of legume and site. In some cases inoculation proved unnecessary or phosphorus addition alone was insufficient. Most striking was the tremendous variability of response to inputs among farms in the same area (Figure 1.2). In most cases, further technology testing led to best-practice management options that were further adjusted to local conditions and local availability of land, inputs and labour, while in others complex suites of limitations were characterized and land restoration options examined.

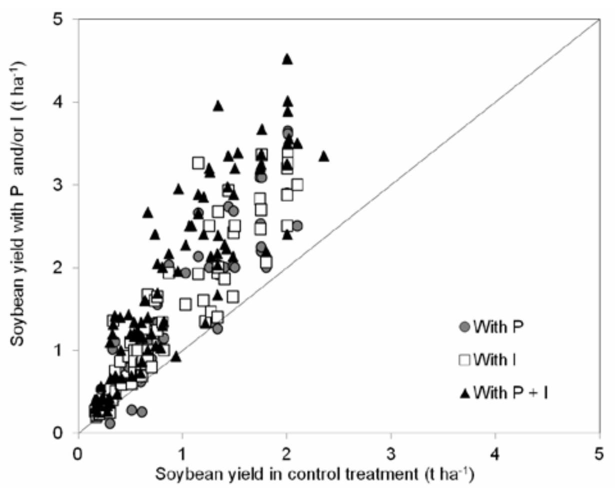


Figure 1.2: Response of promiscuous soyabean to inoculation and/or P fertilizer in demonstration trials in Nigeria.

Learning loops of soil management

The "learning loop" that has identified soil-specific nutrient deficiencies (of K, Ca, Mg, Zn) that have led to legume-specific fertilizer blends being developed and marketed. An example of this loop is the development of Sympal, a fertilizer blended specifically for symbiotic legumes (Figure 1.3). Sympal is described in Section 4. This formulation was developed by field observations over three growing seasons where TSP addition resulted in both pale growth and leaf necrosis, SSP eliminated sulphur deficiency but elimination of basal leaf necrosis required addition of P and Mg. Some sites presented apical striped chlorosis that was diagnosed as zinc deficiency. By the fourth season, MEA Fertilizer Ltd. was producing Sympal at large scale in its Nakuru, Kenya blending plant, offering it in 2, 5, 10 and 50 kg bags. The effects of Sympal versus P-fertilizers in Kenya are striking with an overall yield improvement of 29%, particularly considering that Sympal costs less than the phosphorus fertilizer it replaced (TSP). Similar feedback loops contributed to identification of improved inoculant formulations and application techniques (Section 5).

Figure 1.3: N2Africa research led to the development of Sympal, a new fertilizer specially blended for symbiotic legumes.

Learning loops applied to farming systems

The “learning loop” using farming systems analysis that helps to identify opportunities and constraints of farm (land) size and poverty (lack of livestock and manure) that limit benefits to the poorest - yet the flexibility of legumes means that there are technologies that can be identified as “best-fits” for every type of farmer. For the poorest households, legume technologies such as intercropping, growing short-duration cowpea and bean varieties that provide food early in the season and intensification using climbing beans addressed hunger and food insecurity. The wealthier farmers who have more land, labour and the ability to invest in inputs most easily benefit from engaging with grain legume value chains. Considerable effort was devoted to understanding the diversity of potential beneficiaries to enable the tailoring of technologies to suit their needs.

Figure 1.4: The N2Africa project provided training, resources and peer support that rejuvenated applied rhizobiology in sub-Saharan Africa.

Rhizobiology rejuvenated

Rhizobiology is the study of and application of root nodule bacteria associated with symbiotic legumes. The original goals of the program's Rhizobiology activities were to bio-prospect and select rhizobia for increased BNF (Woomer et al. 2013) and to advance inoculant production capacity in sub-Saharan Africa (Section 5), and these goals were largely achieved. Moreover N2Africa has revitalized Rhizobiology in its eight countries and proven its usefulness (Figure 1.4). To achieve this, it was important to develop a series of field and laboratory protocols related to bio-prospecting and nodule recovery and isolation (Bala et al. 2011), and to train a cadre of technicians and young scientists (Koala et al. 2011). This capacity building then allowed conducting of Need-to-Inoculate tests, collection of 1437 isolates of African rhizobia and identification of 13 elite strains, insight into the better formulation of legume inoculants and expanded inoculant production capacity in sub-Saharan Africa. This team also conducted over 160 inoculation response bioassays using methods compatible with their local facilities (Section 5). An important contribution is the development of inoculant evaluation procedures that contributes to quality assurance in inoculants among technology adopters. Furthermore, this rejuvenation of applied rhizobium research starts to fill the "pipeline" of emerging technologies to enhance nitrogen fixation.

Massive technology dissemination

Table 1.1: Outreach actions of the N2Africa project in eight countries over four years.

Outreach action	total
Lead Farmers trained	3021
Farm households facilitated	252,347
Improved varieties distributed	754 tons
Inoculant packs distributed	142,711
Test fertilizers distributed	451 tons
Satellite households reached	31,299

The massive dissemination of best-fit BNF technologies reached over 252,000 farmers (Table 1.1), 12% over our original ambitious target. These households were provided with improved seed, test fertilizers and where appropriate small packets of inoculants that were aligned with larger field demonstrations and local farmer field days. Farmer training in grain legume enterprise and BNF technology was undertaken in a three-step fashion where a cadre of Master Trainers 24 from all eight countries were trained early in the Program at a single event. Each of these Master Trainers returned to their respective countries and trained a legion of 3012 Lead Farmers in practical application of BNF technologies and farm liaison (Section 7). The Lead Farmers conducted grassroots training among their group members and neighbors, resulting in a small army of farmers empowered with practical knowledge of BNF technologies. Over half (58%) of these farmers are women as grain legume production is often their responsibility (de Wolfe 2012). Note that these beneficiaries also include 31,299 households engaged through development partners that independently adopted N2Africa approaches into their agendas without direct support from the project. While the projects reach was large, its impacts sometimes achieved less than full uptake due to problems with input supply, market access and farmers' purchasing power.

Other achievements

N2Africa's achievements extend beyond these highlights. In all, it involved the committed efforts of over 140 scientists, technicians, farm liaison specialists and others in nine countries, 30% of whom are women (Annex 1). We produced 68 project reports relating to milestone achievements that are available over the www.n2africa.org website (Annex 2) as well as 25 training documents, many in local languages (Annex 3). Numerous videos were produced (79) that documented project activities and are available through an interactive map directory through the project website (Annex 4). N2Africa supported graduate-level training in BNF and extension, with six Ph.D. candidates trained overseas (Section 7), 17 M.Sc. students attending African universities and 8 more trained at Wageningen University (Annex 5), 60% of whom are women. But more than just numbers, it explored new ways of working across countries and institutions to develop, test and deliver needed technology to smallholder African farmers. It started with available technologies and capacities, and directed innovation and training where needed, always examining its impacts at the grassroots. Where input suppliers, supply chains, producer associations and accessible markets were in place, we directed efforts primarily through commercial channels (Rusike et al. 2013). Where public agricultural extension was in place, we partnered with government and where not we linked with others. N2Africa worked largely through farmers' organizations, and placed expectations upon their leaders to operate in transparent and equitable manner. N2Africa worked with agrodealers to make BNF technologies more accessible (Turner and Woomer 2012) and nutritionists and food processors to make grain legumes more useful in household diets (de Jager 2013) and available to local entrepreneurs. N2Africa adhered to its central purpose of putting nitrogen fixation to work for smallholder farmers in Africa through careful, participatory planning, flexible implementation, regular exchange of findings, and applying lessons learned from the thorough monitoring and evaluation.

2 African farmers as clients of BNF technologies

Small-scale farming households in Africa are ideal clients for technologies advancing biological nitrogen-fixation (BNF) by grain legumes because their lands are nitrogen depleted, their diets often contain insufficient protein and they are seeking new income generating farm enterprises. Nitrogen depletion has resulted from decades of traditional cultivation without replenishing soil nitrogen removed as crop harvest or lost from leaching and erosion (Franke *et al.* 2011a). Ironically, these households' low yielding, N-deficient crops persist in an atmosphere rich in nitrogen, but which is unavailable to most crops. That plants never evolved to assimilate atmospheric nitrogen is not only an important evolutionary issue, but also one that greatly reduces the quality of smallholders' soils and lives. Fortunately, several species of bacteria, including symbiotic rhizobia, possess the ability to fix atmospheric nitrogen and have coevolved with many of today's important legumes to allow for management of BNF. This phenomenon is the basis for this project "Putting Nitrogen Fixation to Work for Smallholder Farmers in Africa (N2Africa)".

Smallholder farming systems in Africa are undergoing a transformation from subsistence farming to mixed-enterprise, market-oriented agriculture. It is driven by household desire for higher living standards and recognition that the land alone cannot me*et al.*l of their needs (Table 2.1). This transition is in some cases abrupt, as when smallholders are recruited into large out-grower schemes, but in most cases it is subtle as households more fully recognise that their household needs cannot be satisfied by farming in isolation, and they make stepwise adjustments to improve their production and marketing skills. Greater integration of legumes, particularly pulses, has an important role in this transition because of legumes' versatility as food, feed and cash crops, and their ability to restore soil fertility. The latter is important because households can no longer rely upon inherent soil fertility, fallow intervals or even simple transfers of organic resources to provide yields that secure wellbeing, as result of decades of mining soils of nutrients. The system requires nutrient inputs to restore and increase productivity.

Table 2.1: Selected indicators of living standards across N2Africa action sites (from N2Africa Baseline Survey).

Indicator	Mean	(CV)
Receive non-farm income	15%	(72%)
Have private access to water	26%	(98%)
Own bicycle	44%	(70%)
Live in house with metal roof	50%	(63%)
Own a mobile phone	53%	(34%)
Own a radio	63%	(26%)

Nitrogen is usually the most limiting plant nutrient in soils, but it is not the only one in short supply. Nitrogen in the soil must be limiting for nitrogen fixation to proceed at optimal rates, otherwise the plant will simply absorb it from the soil through its roots. At the same time, other nutrients, particularly phosphorus (Figure 2.1), must be readily available for assimilation by symbiotic legumes (Vanlauwe *et al.*, 2010). In fact, legume crops require greater supply of several nutrients including phosphorus, potassium (Figure 2.1), magnesium, zinc and molybdenum to facilitate nitrogen fixation, which is an energy demanding process. Furthermore, rhizobia must be present in the soil to infect plant roots and to form root nodules in which BNF occurs. Degraded soils often lack abundant and diverse indigenous rhizobia and some host legumes have very

Figure 2.1: Nutrient deficient soyabeans: stunting due to phosphorus deficiency (left) and advanced marginal chlorosis due to potassium deficiency (right).

specific rhizobial requirements. Together these factors require that legumes be inoculated to assure BNF. These particular nutrient and rhizobial requirements are addressed through specialized fertilizers and legume inoculants, which are best marketed together at the time and place where legume seed and other farm supplies are purchased. Unfortunately these products are not available through current farm input supply chains. Identifying which products perform best and improving distributed became an important interdisciplinary activity of the N2Africa project, in order to serve its clients (Turner, 2012b).

N2Africa worked across three agro-ecological zones in Africa: the East and Central Africa Highlands (ECA), the Southern Africa Plateau (SAP) and the West Africa Guinea Savannah (WAGS). These zones exhibit large differences in the patterns of staple crop production (Table 2.2). Maize is widely grown across all zones. East and Central Africa Highlands grow a diversity of other staples particularly cassava, banana, sweet potato and Irish potato (Franke and De Wolf, 2011). This diversity offers opportunity for intercropping and rotations with grain legumes. Maize is the dominant staple in southern Africa. The relatively short growing season and risk of drought discourages intercropping with legumes, whereas the relatively large farm size in Zimbabwe and Mozambique reduced the need. Farmers in the Guinea Savannah also produce rice, sorghum and millet, often in rotation with grain legumes. In the East and Central Africa Highlands we see much more a tendency towards intercropping because of the small farm sizes. As grain legumes are nested into the larger farming system, local adaptation is required for farmers to embrace BNF technologies.

Table 2.2: Frequency of staple crop production by households in the East and Central Africa Highlands (ECA), the Southern Africa Plateau (SAP) and the West Africa Guinea Savannah (WAGS).

Staple crops	Agro-ecological Zone		
	ECA	SAP	WAGS
	--- % of households ---		
Maize	59	96	76
Cassava	56	8	8
Banana	32	0	0
Rice	0	5	45
Sorghum	19	0	42

The frequency of households cultivating the project target grain legumes is presented in Table 2.3 (Franke and De Wolf, 2011). Groundnut and cowpea are grown across all zones, but seldom by a majority of farmers. Soyabean is an emerging crop across all three areas and is well established in Nigeria (40% of households, data not presented). Bush bean is widely grown in ECA and southern Africa and is often intercropped with maize. Climbing bean is popular in Rwanda growing on almost all farms in the northern regions (data not presented). The widespread emergence of soyabean and preference for bean in ECA suggests potential for expanded use of legume inoculants Table 2.4 presents data on size of the land holding and fertilizer use on legume and non-legume crops (excluding cash crops like cotton, coffee or tea) in the mandate areas and action sites of the project that inform potential for increasing production and productivity of legume crops. The small size of land available for arable cropping in Rwanda, Malawi and western Kenya indicates limited possibilities to increase production through expansion in area under legume crops. There is opportunity to increase productivity and improve the role of legume crops within the farming system. Impact will only be achieved by reaching large numbers of farmer households. The overall paucity of use of inputs on these legumes, with only 17% of these crops receiving mineral fertilizers, further underlines the potential for increasing productivity using mineral fertilizer, in combination with or without the use of inoculants. The statistics are strongly influenced by the relatively frequent use of fertilizer on legume crops (especially soyabean) in Nigeria and to lesser extent in Kenya, whereas fertilizer use on legumes is limited in the other countries. Virtually no mineral fertilizer whatsoever

Table 2.3: Frequency of legume cultivation by households in the East and Central Africa Highlands (ECA), Southern Africa Plateau (SAP) and West Africa Guinea Savannah (WAGS).

Legume cultivation	Agro-ecological Zone		
	ECA	SAP	WAGS
	--- % of households ---		
Groundnut	23	53	45
Cowpea	25	27	50
Soyabean	18	19	20
Bush bean	75	22	6

is used in DR Congo to one third of farmers using fertilizer on soyabean in Zimbabwe. The choice of mineral fertilizers for use on legumes is restricted as most available formulations contain nitrogen, which in turn may suppresses nodulation and BNF. P-based fertilizer is readily available and commonly used only in Nigeria. SSP and TSP are available in Kenya but not widely used.

Table 2.4: Size of the land holding and use of fertilizer for legume and non-legume crops in the N2Africa mandate areas (data from the baseline survey).

Country	Landholding size (ha)	Fertilizer use on legume crop (% of fields)	Fertilizer use on non-legume crop (% of fields)
DR Congo	2.0	< 1 %	< 1 %
Western Kenya	1.6[1]	≤ 20% (SB, BB & CB)[2]	46% (maize)
Rwanda	0.7[3]	± 10% (CB)	± 23% (maize)
Ghana	3.0 – 5.0[4]	< 7% (cowpea)	± 62% (maize)
Nigeria	2.7 / 3.5 / 7.0[5]	> 61% (SB), > 30% (cowpea), ± 30% (g/nut)	> 90% (various staples)
Malawi	1.4[6]	≤ 15% (BB, SB and cowpea), ± 35% (CB)	> 90% (maize)
Mozambique	2.9	≤ 15% (BB)[7]	NA
Zimbabwe	1.8[8]	± 33% (SB), ± 14% (g/nut)	± 30% (maize)

[1]. Landholding size class 0.2-0.5 ha is the most frequent with more than 25% of cases falling into this class
[2]. Slight less than 20% for common bean (bush type - BB) and soyabean (SB), and around 21% for climbing bean (CB), but the latter is only grown by very few farmers
[3]. About 33% of farmers have landholding of less than 0.2 ha
[4]. Average landholding size differs for the various mandate areas in Ghana
[5]. Average landholding in Kaduna state south, Kaduna state north and Kano state
[6]. Majority of land holdings are between 0.5 and 1.0 ha
[7]. Use of mineral fertilizers is very limited. Only in one action site mineral fertilizer was use for common bean (bush type) only; for the other action it was negligible
[8]. Majority (42%) is in the class of between 1 and 2 ha; 30% has holdings between 2 and 5 ha

The opportunities for expanded legume enterprise are also influenced by who controls land and legume harvest (Table 2.5). Joint household decision making on the crop to grow (the use of the land) and legume harvest is more common in ECA and SAP than in WAGS. In WAGS, women's control over land and legume harvest is restricted, though women may be allocated a small plot of land for their own use. In all three zones, women have proportionally greater control over legume harvests than over land, often in their capacities as homemakers or through cottage industry processing (Njenga and Gurung, 2011). Knowing who controls legume production is important to how BNF technologies are promoted and packaged.

Table 2.5: Control of land and legume harvest among households in East and Central Africa Highlands (ECA), Southern Africa Plateau (SAP) and West Africa Guinea Savannah (WAGS).

Control of land and legume harvest	ECA	SAP	WAGS
	--- % of households ---		
Land use			
Men	28	32	85
Women	29	21	2
Joint	41	41	11
Legume harvest			
Men	11	22	57
Women	39	25	8
Joint	48	48	33

The future of small-scale farming households largely rests in their abilities to effectively embrace new production and marketing opportunities and the corresponding actions by national planners and development agencies to empower farmer collective action. Hindrances beyond smallholders' control persist, notably weak rural road and utilities networks that in turn result in higher production costs and marketing difficulties (Rusike *et al.*, 2013; Turner, 2012). Agricultural extension is weak and attempts at reform are often ineffective because agents are provided little direction and support. As a result of weaknesses in extension, farmers have formed countless grassroots, community-based organizations in order to better access information and new farming technologies and products. As members expect more from their membership, these groups have grown in size and sophistication to offer needed services such as collective marketing, bulk purchase of key inputs and access to information through diverse channels. Smallholders have adjusted their farming operations toward local and urban markets and make better use of limited available organic resources and purchased farm inputs. The project anticipated and supported these developments and it is within this changing and challenging arena of smallholder opportunities that the N2Africa undertakes its Development to Research approach (Chapter 1).

It is not for the project to decide which BNF technologies and grain legume enterprises should be selected, but rather to identify and promote a suite of opportunities for farmers to test, adapt and, hopefully adopt. Farms vary in resource endowment and the technologies adopted by larger, market-oriented holdings are not necessarily appropriate for others. For this reason, the project tested and promoted different grain legumes, and their roles within farming systems (Dashiell *et al.* 2010; Baijukya *et al.*, 2010) whether in rotation or as intercrops with food staples and cash crops. These efforts were conducted across a range of agro-ecologies and socio-economic settings, using a variety of partnership arrangements. One common element was the focus on the potential for increasing BNF, achieving our quantitative targets, and following a diversified approach towards dissemination for the various countries (Woomer *et al.*, 2012). An array of situations between and within agro-ecologies and countries led to diverse technical options offered to rural communities in East and Central, Southern and West Africa.

2.1 East and Central African Highlands and Midlands

The East and Central Africa Highlands and the adjacent midlands contain great variation in terms of landforms, soils and native vegetation (Franke *et al.*, 2011). The East and Central African Highlands extend from Ethiopia to northern Malawi along the Great Rift Valley including eastern DR Congo, Kenya and Rwanda. These highlands generally have rich soils and abundant, well-distributed rainfall and were once heavily forested. Presently, these highlands host the most productive agricultural region in Africa with coffee, tea and horticultural operations as well as mixed-enterprise and cereal-based small-scale farms. In some cases, these lands have become depleted in nutrienst and subject to generational land division that has resulted in a fragmented landscape and densely populated settlement. The adjacent midlands surrounding Lake Victoria are drier and have less fertile soils, but are also densely populated.

2.1.1 DR Congo

The project works in South Kivu Province to the west and south of Lake Kivu, an area of mountains and valleys. Large differences exist in soils, from highly weathered, nutrient depleted clays to extremely fertile slopes of recent volcanic origin susceptible to extreme erosion. Common bean is the most important legume and farmers grow it for home consumption and sale. Soyabean is a new crop and is becoming important as both food and cash crop. Groundnut is the highest priced legume but markets are not well organized. The bulk of production is used for home consumption. There is no large-scale industrial processing, however some legumes are exported to Rwanda and beyond. Certified seed is not available but farmer groups practise collective bulking of improved varieties. Inoculants and fertilizers are not widely available through commercial channels and there is no commercial inoculant production. There is great promise from legume intensification. Many crops such as maize, cassava and banana are well suited to legume intercropping and marketing channels are opening in the cities and major towns in eastern DR Congo.

2.1.2 **Kenya**

Project activities focuses upon west Kenya, from Migori in the south to Teso in the north and includes lands from the Lake Victoria Basin to the lower highlands. The area has two growing seasons per year and a wide variety of landforms and soils, including extremely weathered and degraded soils in the midlands. Beans are an extremely important crop to farming households and consumers alike, but the productivity of bush bean grown as an intercrop with maize is low. The prices of bean are high in west Kenya throughout the year so there is little motivation to develop supply chains to distant markets. At the project's onset, Kenya had a well-developed soyabean processing industry (producing food, animal feed and vegetable oil) that consumed about 80,000 tons of soyabean, and with little domestic production the bulk is imported. Several soyabean processors in Kenya are willing to purchase domestic soyabeans if prices and quality are comparable to imports. Farmer groups are well positioned to take advantage of this opportunity by establishing community based seed bulking and market collection points, and have done so over the past four years of the project. Kenya hosts developed input supply chains, and produces blended fertilizers and legume inoculants that are actively marketed in west Kenya. Soyabean also induces "suicidal germination" of soil borne seeds of parasitic *Striga* that otherwise causes huge cereal losses and is a major problem in western Kenya.

2.1.3 **Rwanda**

The project operates in the Northern, Eastern and Southern Province of Rwanda. In the Northern Province the action site in in the highland area, whereas in the action sites in the other provinces are in the mid-altitude range. This country is characterized by highly dissected terrain with cultivated slopes and moist valley bottoms (Figure 2.2). Rainfall is bimodal with two growing seasons per year. Common bean is the most important legume, both for household consumption and income generation. Climbing beans were introduced to the country about twenty years ago and account for much of Rwanda's bean production. Several staking systems have developed. Certified seed is not widely available, but the country has developed progressive policies toward fertilizers and legume inoculants. Soyabean is the second most important grain legume and has benefited from many programs that promote its nutritional value. An initiative of the Clinton-Hunter Foundation is construction of a large factory for processing vegetable oil, largely from soyabean. Since recovering from its devastating civil conflict in 1994, Rwanda has reorganized its agricultural research and extension systems, developed a pilot inoculant factory and improved market information services. Women's empowerment is one of the spearheads of Rwandan policy and local and international NGOs play an important role in the rural development.

Figure 2.2: A smallholder homestead in rural Rwanda where grain legumes offer many benefits.

2.2 **Southern Africa**

In southern Africa, N2Africa worked across areas of Mozambique, Malawi and Zimbabwe between 900 and 1500 m in elevation (Franke *et al.*, 2011). This area has pronounced unimodal rainfall with large areas of secondary grassland and lands converted to agriculture. Much of it was covered by Miombo woodland that was cleared for agriculture, first by shifting cultivation and later for permanent mixed farming. Episodic drought occurs in Southern Africa with disastrous human impacts.

2.2.1 Malawi

In Malawi, N2Africa is implemented in a number of districts in the Central Region: Dowa, Lilongwe, Ntcheu, Salima, Kasungu and Dedza. There is one rainy season per year and the country occasionally experiences drought. Groundnut is the most widely cultivated legume. Industrial processing and export marketing has generated high demand but frequent occurrence of aflotoxins hinders commercial supply. Common bean is grown for household food and is informally marketed as mixed varieties. Cowpea is also important to the south for the same reason. Soyabean is becoming important through demand for edible oil and soyabean cake. Total demand for soyabean is around 50,000 tons per year and greatly exceeds domestic supply. Malawi implemented a series of policy reforms that successfully targeted domestic maize production, particularly through the Farm Input Subsidy Program. Seed companies are in place and market legume seed. Because Malawi is landlocked and imports its inputs, prices are quite high, sometimes precluding their profitable use. The country recently initiated a pilot inoculant production facility but prospective importers are finding it difficult to register their products.

2.2.2 Mozambique

N2Africa works in central Mozambique, in Nampula, Zambesia, Manica and Tete provinces. It covers a large geographical area of low population density. Large distances to market centres result in difficulties in input supply, transportation and extension liaison. The country has rebounded from a lengthy civil war and now has active commercial and developmental networks. Some unique features are the large average farm size, the recent emergence of proactive farmer groups and the presence of large commercial farms that attract agricultural services. Groundnut and soyabean are important crops. Several new varieties of both were recently released and buyers are willing to pay premium prices for them. Despite these advantages, commercial delivery of BNF technologies through agrodealer networks is not well developed. No legume inoculants are produced in Mozambique but several brands are imported from South Africa and elsewhere.

2.2.3 Zimbabwe

Zimbabwe has a semi-arid climate that often experiences drought. The project is present in the five provinces in the northeastern region of the country around Harare: Manicaland (Makoni district), Mashonaland East (Goromonzi, Mudzi, Murehwa and Hwedza districts), Mashonaland Central (Guruve district) and Mashonaland West (Chegutu). Common bean, groundnut and soyabean are all important crops. Common bean is important as both a household and cash crop with about 30,000 tons marketed per year. Groundnut is a widely grown cash crop for industrial processing into vegetable oil. Soyabean is grown for sale for processing into oil and press cake used in poultry and swine feeds, with domestic demand of nearly 90,000 tons per year. Soyabean's important role in crop rotation with maize is widely recognized. Zimbabwe has a strong tradition of agricultural research and service provision but have suffered from high staff turnover and underfunding. The infrastructure networks remained largely intact. Contract farming, providing farmers with seed, fertilizer and markets, is relatively well established and has enabled some farmers to deal with high rates of inflation, risky credit and defunct commercial agrodealer operations. Many of the country's soils are sandy and infertile, but developed fertilizer manufacturing is in place and many different blends for crops and locations are produced, but not universally available. Legume inoculants are manufactured and distributed by the Soil Productivity Research Laboratory.

2.3 West Africa Northern Guinea Savannah

N2Africa works primarily in the northern Guinea savannah in Ghana and Nigeria (Franke *et al.* 2011). This zone is dominated by monocrops of maize, sorghum and millet that benefit greatly from rotation with grain legumes. One consideration among farmers is the production of feed for livestock during the long dry season, and legumes offer potential to improve the quality of those feeds.

2.3.1 Ghana

N2Africa's mandate area comprises the Northern Region, Upper East and Upper West regions. Cowpea, groundnut and soyabean are important crops in these regions, but are poorly managed. About 30,000 tons of soyabeans are imported into Ghana per year and substitution with domestic production is high priority. Strong demand for cowpea and groundnut for domestic consumption exists throughout the country. Cowpea leaves are also eaten as vegetable and groundnut leaves used as hay. New short-duration cowpea varieties are fast maturing and one of the first crops to end the hunger season. Constraints include weak farmer organizations and poor access to BNF technologies. Ghana does not produce inoculants. Availability of certified seeds demands attention and only recently private companies were allowed to produce foundation seed.

2.3.2 Nigeria

The project operates in the northern Guinea Savannah zone in Kano, Kaduna and Niger states. Cowpea, groundnut and soyabean are important crops with commercial markets developed around them. Cowpea and groundnut are also important for home consumption. Nigeria is the world's largest producer and consumer of cowpea. Soyabean is primarily grown for market, with processing plants having a capacity of 700,000 tons per year, making Nigeria the largest processor in Africa. Soyabean is increasingly used for home consumption as its nutritional value is increasingly recognised. Nigeria has a culture of cottage industry processing of grain legumes, skills that were quickly applied to soyabean. Ruminant ownership is important and legume residues are seen as an important source of feed. Seed companies produce and market soyabean and cowpea seed, but not groundnut. At the same time, seed bulking by local farmer groups is common. Agrodealer networks are present, but do not market inoculants. Inoculants are not readily available or commonly used in legume production. Fertilizers are imported and sold through government subsidised and open market channels. Fertilizers are mostly used for cereal production.

2.4 Commonalities and Key Differences among countries

Legumes play an important role in the farming systems of all the eight countries and the main legume crops promoted by N2Africa are also those most commonly grown across the project areas. Soyabean production is widespread in Nigeria but less so in the other countries, even where soyabean is imported by food processors. Groundnut is widely grown in Southern and West Africa and is processed into preferred foods for both rural and urban populations (Turner, 2013). Bean and cowpea are important crops for household consumption and in local markets. Yields of the targeted legume crops are poor across the mandate areas of the project and can be increased through judicious use of inputs.

There are marked differences in terms of economic development and poverty among the countries (Table 2.6). Kenya and Ghana have relatively low poverty and relatively high gross net income per capita. This points at better economic development associated with improved infrastructure and availability of farm inputs and suggests favourable conditions for grain legume enterprise. Legume intensification and increased BNF offer opportunities within existing cropping systems with both local and international NGOs ready to assist in the promotion of proven technologies. Nigeria has the highest net income per capita among the eight countries and a reasonable well-developed infrastructure and market access, but wealth is highly unequally distributed with high incidence of poverty especially in the rural areas.

In contrast, farmers in DR Congo, Malawi and Mozambique are very poor. In DR Congo, conditions are particularly acute with very low incomes, small farm sizes and widespread food insecurity, a situation aggravated by intermittent civil unrest. Malawi also has higher population density and small farm sizes, is subject to episodic drought, but has benefited from a series of progressive policy

Table 2.6: Socioeconomic and child health information for the eight countries participating in the N2Africa Project (based upon Franke *et al.*, 2011 – project report 12).

Country	Net income[1]	To urban market	Poverty[5]	Education[2]	Stunting[3]
	$ per capita	maximum hr	-------------- frequency (%) -----------		
DR Congo	$290	9 hours	59	9	46
Ghana	$1,430	7 hours	30	24	28
Kenya	$1,580	3 hours	20	39	35
Malawi	$830	4 hours	53	27	53
Mozambique	$770	8 hours	75	10	44
Nigeria	$1,940	4 hours	64	19	41
Rwanda	$1,010	5 hours	60	4	51
Zimbabwe	n.a.[4]	4 hours	68	70	33

I Income and poverty statistics from World Bank.
[2] Secondary education or greater among 17 to 35 year-olds (based upon N2Africa baseline survey).
[3] Stunting statistics for children under five years old from UNICEF.
[4] n.a. = not available.
[5] Poverty is defined as people living on less than US$1.25 per day.

reforms that were directed toward increasing food production. Mozambique is a vast country with a relatively poor infrastructure, low population density and distant, disorganized markets. All these countries also show high prevalence of stunting among children due to malnutrition, with Kenya, Ghana and Zimbabwe being relatively 'well-off'. This provides justification for the project to put emphasis on the role of grain legumes in improving nutrition and effort in stimulating home consumption of legume crops as means to alleviate the situation. The poorest members of rural communities are generally the worst off. Reaching the poorest and improving their livelihood presents a challenge.

Cattle are important in Kenya, Rwanda and Zimbabwe, and it is in these countries that the project focuses limited attention upon fodder and tree legumes as well as better use of grain legume residues. Groundnut is particularly important in this regard as its nutritious foliage remains green through harvest. Soyabean and bean offer little in this regard as leaf drop is extensive at pod harvest. Use of legume haulms for livestock feed is common in Nigeria, where it is being sold as hay. Use of tree legumes is not likely to offer additional advantage in Nigeria. Large amounts of soyabean meal are imported into Kenya and Mozambique, as well as the other N2Africa countries, largely for use as poultry feed. Opportunity exists in all countries to improve the use of legumes as animal feeds, but with large differences in how they are best realized.

In northern Nigeria, gender roles are strict and separated. Women organize in separate groups and access local markets through separate channels. The dissemination approach needs to reflect this in organizing events like demonstrations and field days. In other countries, grassroot efforts can target local groups that are more responsive to gender equity. One important common feature across these countries is the role of women in processing legumes for household consumption and local sales, to the benefit of family members and the community as a whole.

2.5 **Targeting project intervention**

Grain legumes have a high demand and promotion of BNF technologies requires that value chains be strengthened (Rusike *et al.* 2013), targeting food self-sufficiency and import substitution. Strengthening of the value chain is premised upon increasing production volume and increasing production is achieved either through expanded production area or through increased legume productivity. Apart from that delivery and quality of the product plays a role. Top-end buyers require consistent supply and quality, and that contracts be honoured in a timely manner at agreed prices. Unless smallholder farmers belong to well-organized groups, they have difficulty in complying with these provisions. N2Africa therefore pays attention to the organization of farmers and strengthening of the farmer organizations. The level of farmer organization (organizational infrastructure) and strength of these organizations differs considerable between the various countries. Furthermore, the input supply system, with regards to improved legume varieties, rhizobial inoculants and specialized fertilizers, are an important aspect of the value chain. The capacity of the input supply system varies greatly between countries (Woomer *et al.*, 2013). After many years of breeding, many grain legumes possess outstanding yield characteristics and pest and disease resistance but have not been licensed by commercial seed producers, for example. Only Kenya produces inoculants commercially, and there are constraints to cross-border movement and registration in neighbouring countries. Accompanying technologies such as agro-chemical supply, tractor and machinery hire services and access to credit also pose obstacles to farmers seeking to expand legume enterprise.

Project interventions to address these constraints include the testing and promotion of new varieties adapted to local agro-ecological conditions, improving crop and post-harvest management practices, improving the input supply systems for seeds, inoculants and fertilizers, supporting and developing farmers' organizations and better linking them to markets. Farmers cannot determine the quality of inoculants at purchase so quality assurance programs have been put in place. Finally, training and alignment of agrodealers to both suppliers of BNF technologies and producer associations is another means to strengthen value chains. The baseline survey and characterization of the N2Africa mandate areas provided a useful backdrop against which the project impact is assessed. The devolved structure of N2Africa allowed a differentiated Development to Research approach to identify which constraints exist and how they may be best resolved in order to achieve impacts from "putting biological nitrogen fixation to work for smallholder farmers in Africa".

3 Program Impacts: Achieving our Vision of Success

The overall goal of the N2Africa Project is to improve human nutrition and farm income while enhancing soil health, and its approach toward this goal is quantitative and measured. The Vision of Success was to raise average grain yields by 954 kg/ha in four legumes (groundnut, cowpea, soyabean and common bean), increase average biological nitrogen fixation (BNF) by 46 kg ha^{-1}, and increase average household income by $465, directly benefiting 225,000 households (about 1,800,000 rural inhabitants) in eight countries in sub-Saharan Africa (DR Congo, Ghana, Kenya, Malawi, Mozambique, Nigeria, Rwanda, Zimbabwe). Overall, N2Africa sought to triple the inputs of free atmospheric nitrogen by biological nitrogen fixation within these farms through the promotion of legume and rhizobial inoculant technologies. In this way, the project links the protein and nitrogen needs of poor African farmers directly to previously inaccessible, massive atmospheric reserves, provides them with new income-generating crop production enterprises, presents a mechanism of renewable soil fertility management and opens the door to the adoption of numerous, accompanying farm technologies and value-adding enterprises (Woomer *et al.* 2012). Indeed, this is a challenging suite of targets upon which to evaluate the effectiveness of our Development to Research approach.

Project research was guided by a conceptual model of productivity where grain legume yield and N_2-fixation is a function of $G_L \times G_R \times E \times M$. Basically, this states that the yield and BNF attainable from a farming system is a function of the genetic potential of its legumes (G_L) and rhizobia (G_R) as conditioned by its environment (E) including soil environment and weather and is strongly influenced by agronomic management (M). This model framed our research in legume agronomy and rhizobiology in a manner that evaluated current smallholder varieties and management and provided sets of locally-adjusted "best bets". The project's quantitative targets were then approached through the effective dissemination of these BNF and accompanying technologies, and their incorporation in local agricultural development agendas (Turner and de Wolf, 2012). Evaluating the progress in these areas required that communities within defined agro-ecological zones be identified where BNF is deficient and expanded legume enterprise offers promise, that an accurate baseline be established within these Action Sites, effective "best-practice" interventions be designed and tested, and partnerships be established around their dissemination. While intervention and partnership strategies varied between country and community, progress was seasonally monitored through a standardized set of report forms (de Wolf, 2013), and culminated in a comprehensive Early Impact Assessment near the end of the project. This impact assessment involved a household survey in each of the eight countries to assess current, independent use of N2Africa technologies; a survey of agrodealers to document the availability of legume inoculants and other inputs needed for best practice and miscellaneous case studies that examine several aspects of farmer adoption and access to inputs that were difficult to assess through the first two structured surveys.

3.1 Achieving our Vision of Success

An impact assessment was included as an important Year 4 activity to quantify gains among its communities and stakeholders. As most of these benefits are accrued among small-scale farmers, a household survey was conducted. General information described household members, their education, farm animals and sources of income. Other sections covered input use, farm enterprises and field areas with emphasis upon nitrogen fixing legumes, crop production and yields, changes in land use, and legume processing and household nutrition. A random sample of 300 households was selected from each country, stratified by gender, level of training in BNF technologies and other locally applicable criteria and results were compared to the N2Africa baseline survey. These interviews were conducted in early-to-mid-2013 after conclusion of the previous season. The number of direct beneficiaries of the project was determined through routine monitoring over four years.

The quantitative targets of the project were exceeded in some ways, and almost met in others, but our ability to close forecasted yield gaps was under-projected. The number of direct beneficiary households reached introduced to BNF technologies was 253,299, or 12% greater than expected. These beneficiaries do not include the 31,299 households working with partners that independently adopted N2Africa approaches into their agendas without direct support from the project.

Table 3.1: A summary of the seasonal impacts achieved through BNF technology dissemination over four years by the N2Africa Project.[1]

parameter	baseline	after 4 years	change	increase	impact[2]
farmer yield (kg grain ha^{-1})	1,001	1,147	+ 146	15%	146 kg grain ha^{-1}
legume area (ha $farm^{-1}$)	0.18	0.35	+ 0.17	94%	42,899 ha
legume harvest (kg $farm^{-1}$)	179	397	+ 218	122%	55,012 t grain
crop value ($/ $farm^{-1}$ $season^{-1}$)	154	378	+ 224	145%	$56.5 million
BNF (kg N $farm^{-1}$)	10	28	+ 17	169%	4,388 t BNF N

[1] Average across countries and target legumes not weighted by household number, seasonal impacts do not consider three countries (DR Congo, Kenya and Rwanda) with two growing seasons per year. [2] Calculated as number of impacted households (252,347) x change in parameter, value does not include residual benefits to following crop (≈ $8.6 million)

Table 3.2: Targets and progress made towards achieving the Vision of Success.

Target	Achievement
Directly benefit 225,000 households	253,299
To increase grain legume yield by 954 kg ha^{-1}	
for bean	+ 139 kg ha^{-1}
for cowpea	+ 117 kg ha^{-1}
for groundnut	+ 78 kg ha^{-1}
for soyabean	+ 272 kg ha^{-1}
To increase BNF by 46 kg ha^{-1}	
for bean	+ 22 kg N ha^{-1}
for cowpea	+ 9 kg N ha^{-1}
for groundnut	+ 7 kg N ha^{-1}
for soyabean	+ 41 kg N ha^{-1}
To increase average household income by $465	$355

Increases in crop yield, cropping area devoted to legume enterprise and legume harvest are presented in Table 3.1 and Table 3.2. The assessment of the impact of N2Africa technologies on legume yields and BNF is based on responses of legumes to the application of inputs in N2Africa's dissemination and demonstration trials and the current use of N2Africa technologies assessed in the Early Impact Assessment. The increase in average grain yield is a weighted average amongst the different categories of adopters (e.g. in the case of soyabean: 'no use of inputs', 'inoculants only', 'P fertilizer only' and 'full adoption'). Not all farmers use all components of the legume package in their own fields and a considerable percentage does not use any of the inputs (Table 3.3). We see marked differences between countries in the adoption of the technology. Kenya stands out with the high rates of full adoption of the soyabean technology (61%). In Nigeria we see high partial adoption rates (only 6% that does not use any inputs for soyabean). In Nigeria we also see high adoption in the use of fertilizers for the cowpea and groundnut (82% and 76% respectively). Generally the use of inputs (inoculants and/or fertilizer) for beans, cowpea and groundnut is considerably less than with soyabean, with Zimbabwe and Ghana scoring particularly low. The greatest success in raising legume yields and BNF was experienced with soyabean and bean, crops that synergistically respond to inoculation with rhizobia and improved fertilization. The lower yield increases observed in cowpea and groundnut are largely attributed to better agronomic management in absence of inoculation.

Table 3.3: % of farmers using different components of BNF technologies based upon the N2Africa Early Impact Assessment (bold denotes recommended practice).

Country (crop)	non-adoption	inoculant only	P fertiliser or blend	fertilizer & inoculant
	---------------------------------- % --------------------------------------			
DR Congo				
soyabean growers	34	27	23	**16**
bean growers	57	8	27	**8**
Kenya				
soyabean growers	14	9	16	**61**
Rwanda				
soyabean growers	55	10	18	**17**
bean growers	72		28	
Ghana				
soyabean growers	69	6	19	**6**
cowpea growers	90		**10**	
groundnut growers	85		**15**	
Nigeria				
soyabean growers	6	11	57	**26**
cowpea growers	18		**82**	
groundnut growers	24		**76**	
Malawi				
soyabean growers	50	10	15	**25**
cowpea growers	77		**23**	
groundnut growers	91		**9**	
bean growers	67	4	27	**2**
Mozambique				
soyabean growers	34	27	23	**16**
groundnut growers	93		**7**	
Zimbabwe				
soyabean growers	69	16	11	**4**
cowpea growers	83		**17**	
groundnut growers	97		**3**	
bean growers	60	2	36	**2**

Neither of the targets for yield increase and BNF were met on a per unit-area basis, in part because the baseline yields where somewhat greater (14%) than the figures used in the original calculations. This shortcoming was counteracted by the 94% increase in farm area devoted to grain legumes resulting in a 2.2-fold increase in legume harvest, presumably because of the incentives for expanded enterprise offered through the project's technology dissemination activities.

Seasonal farm income increased by $245, but this estimate does not take into account the agro-ecological zones permitting two crops per year. Adjusting for the two growing seasons in DR Congo, Kenya and Rwanda increases average income to $355 per household per year, while the target was set at $465. Economic benefits are based upon partial budgeting with not all costs, particularly labour, included due to lack of reliable data. Note that the overall baseline seasonal BNF of 10 kg N per farm was increased nearly threefold. *When the number of participating households is considered (253,299), the impacts of our BNF technology dissemination reached about 43,000 additional ha resulting in 55,000 tons increased grain worth about $56.5 million. This value does not include residual benefits to following crops estimated to be another $8.6 million. If the project's $19.2 million investment is considered, its return to donor investment is 3.4-fold.*

When results are expressed by individual country and individual crop, it is clear that different degrees of BNF technology adoption exist (Table 3.3). A minority of farmers use all components of the legume package in their own fields and a considerable percentage did not adopt either inoculant or fertilizer. The greatest degree of adoption was observed with soyabean in Kenya where both input and commodity value chains are most advanced. High partial adoption rates were also observed in Nigeria, including use of fertilizers for the cowpea and groundnut. In part, weak adoption in many countries, particularly Ghana, Malawi and Zimbabwe, is attributable to these products not being available through agrodealer networks, because best-practice recommendations outpaced input supply.

At the same time, non-adoption results when best-practice technologies fail to perform as expected. This situation is illustrated in Figure 3.1 where the baseline yields, average new on-farm yields, average best-practice yields and the yields in 25% best performing fields in N2Africa's dissemination and demonstration trials (indicative for attainable yields), are compared for bean, cowpea, groundnut and soyabean. Clearly, N2Africa best-practice offers marked potential but more so under the best management and growing conditions. Farmers' reluctance to invest in technologies they view as risky is conditioned by their individual experience with underperforming BNF technologies as illustrated by Figure 3.2 and Figure 3.3 both relating to the adoption of soyabean technologies in two different countries, Mozambique and Nigeria.

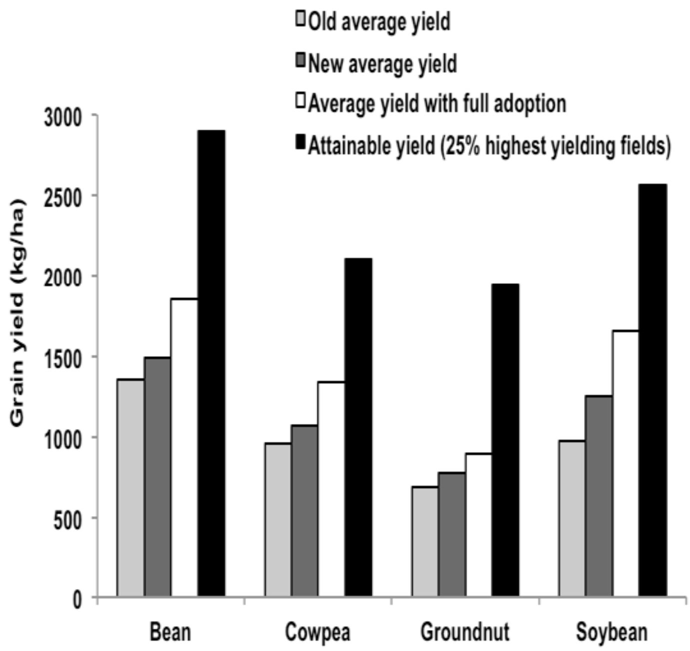
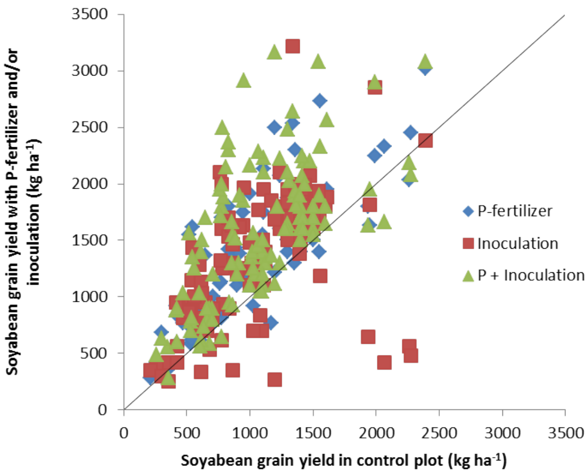


Figure 3.1: Comparison of baseline (old) yield, new yield with adoptive use of N2Africa, yield achieved with complete use of N2Africa technologies, and yield obtained from the top 25% of technology tests.



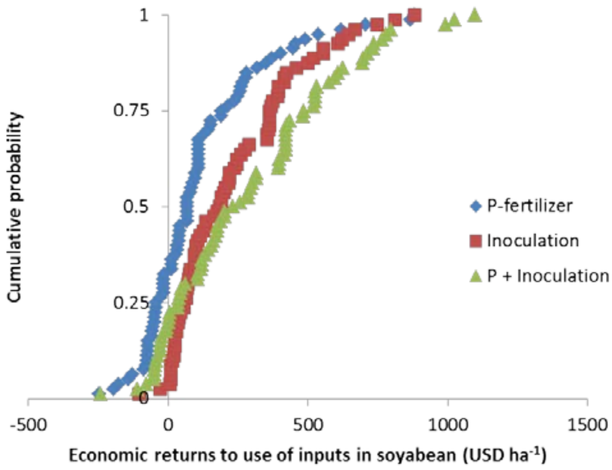


Figure 3.2: Soyabean yields from individual demonstration and dissemination plots in Mozambique resulting from partial and complete adoption of best-practice BNF technologies, plotted against the control yield.

Figure 3.3:The cumulative frequency of economic returns to partial and complete adoption of soyabean best practice in northern Nigeria.

While at many sites soyabean responds to additions of fertilizer and inoculants in Mozambique, especially in conjunction, others do not as evidenced by the large number of points that cluster around the 1:1 line (where yield using one or both of the inputs does not differ much from the control yield), especially evidenced by instances of poorly yielding farms appearing in the lower left of Figure 3.2 (region of lower control yields). The same phenomenon is expressed for Nigeria in Figure 3.3, but in a different manner that identifies the frequencies of economic return to partial and full adoption of fertilizer and inoculant. These findings have important ramifications. Many farm households stand to benefit from adopting our best-practice BNF technologies (Figure 3.4 and Figure 3.5), and full adoption is best, but at the same time many other households operate in site-specific conditions where the best-practice fails to increase yields. In the case of Nigeria, this is about 30% of the farms. This trend occurs across all participating countries and points to both poor agronomic management and at the lower end of the response curve, the prevalence of non-responsive soils. This highlights the need for more site-specific solutions.

Figure 3.4: Soyabean best practice in Zimbabwe (left) compared to non-adoption of inputs (right).

Figure 3.5: Farmers view a well performing soyabean crop in Mozambique, but many other farms failed to respond to best-practice management promoted by the project.

This variability in response to best-practice greatly affected the profitability of the promoted technologies for many farmers. The average yield in the 25% highest yielding farms (Figure 3.1) provides indication of attainable yields and that more complete technology adoption increases yield, but also that attaining the N2Africa Vision of Success requires more careful selection and promotion of technologies to close the yield gaps. Other anticipated impacts of technology promotion and their role in improved food security and nutrition require further attention. The project succeeded in increasing the availability of grain legumes at the household level but assumes that benefits accrue through sale of grain, while value-adding processing and local product sales continue. The N2Africa evaluation was somewhat premature to identify the full scope of benefits as at least 5-10 years are required for full impact to develop, especially among the majority of farmers joining the project in its later stages.

3.2 Agrodealer delivery of BNF technologies

BNF technologies must be widely marketed by local agrodealers for them to be readily available to small-scale farmers. Towards this end, it is important that the project understands which products are available, how often they are marketed, and where BNF technologies stand with respect to other products. Among these products are seed of target grain legumes, fertilizers not containing nitrogen and rhizobial inoculants. During its final year, N2Africa conducted a survey among agrodealers operating in the Action Areas of seven countries. This survey captured the overall business setting of agrodealers and their marketing of BNF technologies (Table 3.4).

Table 3.4: Frequency of marketing BNF technologies by agrodealers in seven N2Africa countries.

N2Africa country	Seed of target legumes	Legume inoculants	Legume fertilizers
	-------------- % of retailers marketing ------------		
DRC	50	0	0
Ghana	32	2	3
Kenya	85	45	47
Malawi	79	21	7
Mozambique	80	14	2
Rwanda	50	67	0
Zimbabwe	53	15	12

In all, 241 business operations were assessed with 77% of respondents being owners and 24% women. The number of interviews varied among countries from only four in DR Congo and 60 in Zimbabwe. This reflects the difference in input distribution networks in the various countries. In DR Congo there are few agro-dealers or stockists in the rural areas. The four agro-dealers interviewed are all larger shops located in Bukavu, the regional capital, indicating that access to agro-inputs is a problem in the region. The results are skewed toward countries with the larger representation of agro-dealers in the field.

Overall, business operations are stable with an average nine years in operation but 26% were more recent start-ups with three years or less in business (Table 3.5). A majority of these businesses are certified by local authorities to market agricultural inputs (69%) and participated in N2Africa agrodealer training (53%). Many belong to agrodealer associations (40%). About half of these agrodealers receive credit from suppliers and extend credit to customers, but few receive credit from banks (29%) and a majority consider overall credit relations unsatisfactory (67%). Marketing inputs for cereals is more common than those intended for grain legumes, but a majority market at least one of the program's target grain legumes (61%). Unfortunately relatively few market legume inoculants (20%) or fertilizers suitable for legumes (14%). One promising signal is that 36% of agrodealers have refrigerators and 48% of inoculants are stored under refrigeration.

Table 3.5: A profile of agrodealer operations in N2Africa countries.

Survey query	Response
Interviews (n)	241
Owner interviewed	77%
Woman interviewed	24%
Years in business	9
Markets maize seed	76%
Certified business	69%
Markets urea	65%
Markets legume seed	61%
Provides credit	59%
Receives credit	47%
Association member	40%
Markets inoculant	20%
Markets legume fertilizer	14%

Large differences in marketing BNF technologies also occur among countries. While grain legume seed is widely marketed, some countries offer little or no legume fertilizers or inoculant (DR Congo, Ghana and Mozambique). The inoculant products from two countries with pilot inoculant production started through N2Africa (Malawi and Rwanda) are appearing on stockists' shelves, but this observation may be confounded in that the same partner producing inoculants also organized the survey campaign. Relatively few inoculants are marketed by local agrodealers despite decades of inoculant production by a state owned organization in Zimbabwe. Only agrodealers in Kenya have established reliable supply of BNF technologies through commercial channels, but slightly less than half of these retailers offer both inoculants and fertilizers suitable for legume cultivation. Zimbabwe is the only other country where legume fertilizers are available to some extent with approximately 10% of retailers selling. It is likely that the paucity of legume fertilizers is more related to what is available within the country than to what stockists choose to carry. Indeed, an important means to support legume enterprise is to further commercialize fertilizer blends specifically formulated for symbiotic grain legumes.

Figure 3.6: Many agrodealers were introduced to legume inoculants through training and test marketing by N2Africa but the lack of wholesale suppliers reduced their subsequent access to stock.

Ideally, improved legume seed, quality inoculants and specialized fertilizer blends should be offered for sale at the same time and place and, owing to a lack of balanced input pattern, this becomes a priority for the promotion of grain legume enterprise in the future. Further rounds of training are needed to strengthen agrodealer participation in marketing BNF technologies. Agrodealers should consider including inoculated and adequately fertilizing grain legumes in their local roadside product demonstrations that are usually dominated by cereal production technologies. Suppliers must more actively market BNF technologies by extending products on consignment and distributing promotional materials (Figure 3.6). In some settings, legume technologies are more effectively promoted through farmer cooperatives connected to product suppliers, with key inputs extended as a service to members at a discount. Because inoculants must be either produced or freshly imported before each growing season, agrodealers are advised to prepare and consolidate their orders in a timely manner. Suppliers must develop policies to replace expired stock. These results suggest that N2Africa has effectively linked with the private sector in some countries and may serve as a counterfactual for determining the impacts of BNF technology promotion by the commercial sector in the future.

3.3 Illustrative case studies

Case studies were commissioned by N2Africa on a wide range of topics (Annex 5). The purpose of these studies was to collect information on approaches and outcomes that would otherwise have been missed through routine M&E efforts or through meta-level analyses. In this way, detailed information was captured from all countries on success stories that complement the N2Africa Early Impact Assessment. Of particular interest were in-depth studies on adoption of BNF technologies and how they are tailored to local conditions.

Cooperating organisations were invited to submit case study topics that were evaluated by a selection team at Wageningen University in consultation with Country Coordinators. Studies were then selected based upon their complementarity with the N2Africa goals. In total, 17 studies were commissioned across a range of topics in all eight countries. In some cases, the same study was conducted in more than one country for purposes of comparison. An overview of these studies is presented in Table 3.6. Several key findings emerged from these studies.

Table 3.6: Topics and locations of N2Africa case studies.

Production systems

- ☑ Potential and challenges of climbing bean production in Western Kenya
- ☑ Seed systems and sources of inputs in Mozambique
- ☑ Legume cultivation and gender in Northern Nigeria

Technology adoption

- ☑ Adoption and adaptation of BNF technologies in DR Congo.
- ☑ Factors influencing soyabean production and willingness to pay for inoculant in northern Ghana
- ☑ How farmers acquire and share N2Africa knowledge and technologies (four countries)
- ☑ Farmer’s adaptations of technologies (five countries)
- ☑ Activities of a model Lead Farmer in Malawi
- ☑ The Lead Farmer approach: An effective means of agricultural technology dissemination in Zimbabwe

Marketing

- ☑ Performance of the grain legume marketing systems in Northern Ghana
- ☑ The soyabean market situation in Western Kenya: constraints and opportunities for smallholder producers

Nutrition

- ☑ Soyabean milk processing and marketing in Malawi
- ☑ Nutritional benefits of grain legume cultivation in Northern Ghana and in Western Kenya

Farmers adapt N2Africa technologies based upon exposure to field demonstrations and other grassroots activities. Examples include change from monocropping to intercropping, adjustment of plant spacing, combining improved and local legume varieties and delays in planting time to reduce pest pressure and improve ripening conditions. Some farmer adaptations reduce workload and maximize land area without necessarily increasing yield.

The effectiveness of Lead Farmers in grassroots technology dissemination depends upon how they are selected. The best Lead Farmers tend to have more education, previous training in other technologies, and higher socioeconomic status. In some cases, there are few qualified Lead Farmers, suggesting that approaches with higher training ratios are more suitable.

Farmer-to-farmer diffusion of BNF technologies continues. A main mechanism is the sharing of seed with neighbours. Once aware of new opportunities, many of the indirect beneficiaries seek out the N2Africa staff. Spontaneous technology dissemination is difficult to monitor across the entire Program but examples of how farmers spread and pursue BNF technologies is important in designing future dissemination campaigns

Several different pathways of grain legume marketing occur. As production increases, wholesaling to top-end buyers becomes more feasible but profits are often not equitably distributed along the marketing chain. Fairer shares to smallholders result from improving credit availability, reducing the cost of transportation, improving road and market information infrastructure and accessing storage facilities following peak harvest. Collective marketing by farmer groups offers some of these advantages but managers require business skills (Figure 3.7). Localized marketing to schools, hospitals and shops may offer higher prices.

Figure 3.7: A smallholder soyabean marketing collection point in Kenya.

Preliminary study in northern Ghana suggest that children of N2Africa participants enjoy better diet than non-participants (Figure 3.8). This improvement results both from home consumption of legumes and greater household income. Women farmers direct legumes toward household needs more than men, particularly after receiving training in grain legume processing.

Studies that addressed specific knowledge gaps or were conducted across different countries tended to be most effective. The need for case studies was identified from observing the influence of N2Africa that was not being captured in regular M&E. Most studies were conducted during the final year and these studies offer an alternative, more detailed perspective on field activities, particularly technology adoption at the grassroots level. Commissioning such studies earlier in the project, and linking them more closely with ongoing country activities, however, would improve their contributions to wider learning. Additional information on the N2Africa case studies can be found in Annex 5.

Figure 3.8: Assessing child nutrition in Ghana.

3.4 **Conclusion**

While N2Africa perhaps fell short of achieving its quantitative targets on yield and BNF per unit area across all of the farmers reached, it had a profound impact within the farming communities where it operated. Through the promotion of carefully selected and tested BNF technologies, it reached more than the expected numbers of households who expanded their land areas devoted to grain legumes and increased their production through adoption of best-practice management. Adoption was incomplete, and in some cases limited. This failure was due to a number of reasons, the lack of access to inputs due to absence of supply chains, the lack of cash to invest in inputs, the risk associated with variable response to the technologies. Selected case studies further elaborated upon technology adoption and rural input and commodity markets. The development and promotion of N2Africa best-practice, and its successful impacts are built upon our Development to Research model. The details of the N2Africa approach to legume agronomy, rhizobiology and inoculant delivery, technology dissemination and capacity building are described in the following Sections 4 through 7.

4 Improved Management of Symbiotic Legumes

N2Africa identified the best grain legume varieties and their appropriate management practices for integration into African smallholder farming systems. Emphasis was placed upon readily marketable commodities and multi-purpose legumes providing food, animal feed and high quality crop residues. A stepwise approach was taken to deployment of legume and inoculant technologies with strong BNF capacity, focusing initially on 'quick-wins' employing existing proven technologies, allowing N2Africa accelerated engagement with farmers from the start of the project. The Legume Agronomy team conducted a series of interacting studies that first acquired promising varieties of bean, cowpea, groundnut and soyabean, comparing them to current lines for yield, N_2-fixation capacity and adaptation to abiotic and biotic stresses and then assigning best-fit agronomic practices to them (Baijukya and Vanlauwe 2011). The potential of multi-purpose tree and forage legumes was also assessed (Baijukya and Giller, 2012). The contributions of improved legume varieties next to best-fit agronomic practices were examined within the context of system productivity and farm livelihood (Franke *et al.* 2013). Finally, several of the best legume interventions are described in a socio-economic and agro-ecological context.

4.1 Mobilizing the best varieties

Given the short time-scale of the project, the legume germplasm focus was on selection of varieties from the genetic material already available from other breeding programs, with strong potential for BNF (Dashiell *et al.*, 2010). New and experimental varieties of bean, cowpea, groundnut and soyabean with high N_2-fixation capacity and adaptation to abiotic and biotic stresses were identified, acquired and compared to currently available material. In this way, elite grain legume varieties with high BNF potential and farmer-accepted agronomic characteristics were passed to the BNF Technology Dissemination team for on-farm testing within its participatory field campaigns and bulking through community-based actions.

Table 4.1: Grain legume varieties and fodder legume species evaluated for BNF potential in different countries.

Country	Bean	Cowpea	Groundnut	Soyabean	Fodder legumes	Total
DR Congo	8	0	0	12	11	31
Ghana	0	21	21	11	0	53
Kenya	23	0	0	16	15	54
Malawi	10	0	0	25	0	35
Mozambique	0	0	8	15	0	23
Nigeria	0	12	10	12	0	34
Rwanda	14	0	0	32	8	54
Zimbabwe	8	0	0	8	6	22
Total	63	33	39	131	40	301

In total, 266 varietal tests were conducted across the project (Table 4.1). Nearly half of these evaluations were conducted using soyabean. Ghana and Rwanda were particularly adept at varietal evaluation, conducting 37% of these studies. To a large extent the numbers of varieties evaluated were conditioned on the assigned target grain legumes, as no country worked with all four crops (Baijukya *et al.*, 2013). Nine best soyabean varieties, six best bean varieties, six best cowpea varieties and seven best groundnut varieties with high BNF potential, good yield and farmer-preferred characteristics were identified (Table 4.2). The amounts of N fixed by the selected varieties is highly variable (in the range of 101-156 kg N ha^{-1} for soyabean, 50-88 kg N ha^{-1} for bush varieties of common bean, 48-132 kg N ha^{-1} for cowpea and 50-65 kg N ha^{-1} for groundnut) but they indicate considerable potential for increasing N availability in the farming systems.

Table 4.2: Soyabean, common bean, cowpea and groundnut varieties selected for high BNF, grain yield, preference by farmers and or market in project Impact Zones.

The target values for BNF set by N2Africa are 110 kg N ha^{-1} for soyabean in East, Central, West and Southern Africa; 51-60 kg N ha^{-1} for common bean in East and Central Africa and 34 kg N ha^{-1} in Southern Africa; 55 kg N ha^{-1} for cowpeas in West and Southern Africa; and 45 kg N ha^{-1} for groundnut in West Africa and 60 kg N ha^{-1} in Southern Africa. Data in the parenthesis indicate % increase from the target BNF values.

	East & Central Africa		West Africa		Southern Africa	
	Variety	N-fixed (kg ha^{-1})	Variety	N-fixed (kg ha^{-1})	Variety	N-fixed (kg ha^{-1})
Soyabean	SC Saga	124 (13%)	SC. Saga	138 (25%)	Makwacha	118 (7%)
	TGx1740-2F	119 (8%)	Salintuya	156 (42%)	TGx1740-2F	128 (16%)
	TGx1987-62F	125 (14%)	TGx 1448-2E	153 (39%)	TGx1485-1D	124 (24%)
					TGx1904-62F	199 (81%)
Common bean	Kenya Tamu	166 (176%)				
	RWAV 1348	288 (205%)	NA		Data not included due to poor performance of trials	
	GASIRIDA	165 (223%)				
	AND10	167 (178%)				
	RWR 2076*	90(76%)				
	RWR 2245*	80 (57%)				
	Tsimbindi*	71 (39%)				
Cowpea			Apagbaala	155 (66%)	Sudan 1	112 (103%)
	NA		Songotura	62 (12%)	IT97-1069-6	99 (80%)
			IT99K-573-1-1	61 (11%)	IT82E-16	142 (158%)
Groundnut	NA		EVDT	50 (10%)	ICGV - SM 83	61 (26%)
			SAMNUT21	52 (15%)	ICGV SM 99568	65 (16%)
			RMP12	47 (2%)	ICGV - SM 90704	61 (16%)
					ICGV 12991	62 (16%)

* Bush bean variety; NA = not applicable.

For soyabean, the identified varieties are high yielding (above 1,500 kg ha^{-1}) with early maturity period (110-120 days), are resistant to shattering and are in greater demand by buyers. The Seed Co. variety

SC Saga is resistant and the IITA variety TGx1987-62F tolerant to soyabean rust disease. Surprisingly, many of the older varieties are preferred by farmers (e.g. TGx1740-2F, TGx1448-2E, TGx1485-1D, Salintuya and Makwacha), and are adapted across the Impact Zones e.g. TGx1740-2F and SC Saga. This finding strongly supports N2Africa philosophy that BNF can be increased significantly by enhancing the productivity of already existing legume varieties.

Many of the identified common bean varieties are climbers, except the three bush types (Table 4.2). The characteristics of the varieties preferred by farmers are ‘high yielding’, ‘fast growing’ and ‘less susceptibility to common bean diseases like anthracnose and root rot and to pests like aphids and rot knot nematodes’. Grains of climbers RWV 1348 and AND 10, and bush type RWR 2076 and RWR 2245 are high in Fe and Zn contents. For cowpeas, apart from high yields obtained, farmers prefer the varieties because of their early maturity, resistance to *Striga* and *Alectra* and are tolerance to drought. The selected groundnut varieties in West Africa are dual purpose (producing grain and haulms for fodder), are tolerant to rosette disease and are high in oil contents (>50%). Groundnuts varieties selected in Southern Africa are high yielding (about 2 t/ha), early maturing (90-120 days) and are tolerant to rosette disease. Certainly, comparison of best varieties of these grain legumes warrants more analysis to assess whether the BNF they achieved provides a positive N balance to the crop and provide for long-term sustainability.

4.2 **Improving grain legume management**

Proven and flexible best-fit management practices are required to realize the potential of improved varieties' higher yields and accrued household benefits. A process was developed that first assembled current farmer practice and existing management recommendations, than designed candidate improved approaches and tested them together in the field (Figure 4.1). This process grew in sophistication over time. First grain legumes were tested for response to applied phosphorus and then the need for additional nutrients was explored. Other management factors were also considered such as optimal plant spacing, pest and disease management and staking systems for climbing bean. Finally, these management practices were applied within a wider farming systems context as understorey intercrops or in rotation with cereals. In this way, proven agronomic guidelines supporting grain legume production, and cereal-legume intercropping and rotation were included within the extension messages delivered to farmers in conjunction with the field campaigns of the BNF Technology Dissemination team and published for distribution to other farming, development and research organizations (Turner, 2012). In some cases, soils were identified where crops failed to respond to recommended practice, and options for special management and rehabilitation were explored as discussed below.

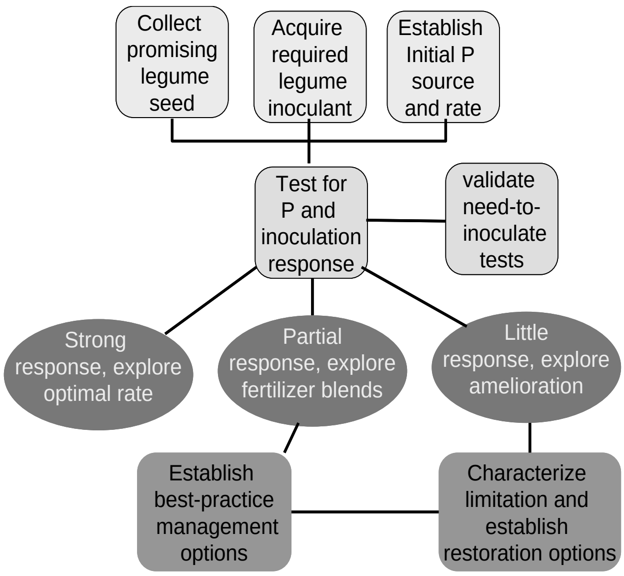


Figure 4.1: The stepwise approach to developing best-practice management options employed by N2Africa.

4.2.1 **P as a key input**

Adaptive research campaigns were initiated across N2Africa mandate areas to assess the responses of target legumes to the application of phosphorus (P) fertilisers (Vanlauwe *et al.*, 2010). Combinations of rhizobia inoculants and P addition were examined on common bean and soyabean. The P-based fertilizers applied depended on availability in different countries. Triple Super Phosphate (TSP) was available in most countries including DR Congo, Ghana, Kenya, Rwanda Zimbabwe and Malawi. Single Super Phosphate (SSP) was marketed in Kenya, Nigeria and Mozambique and offers the advantage of containing calcium and sulphur, often lacking in sandy and highly weathered soils. Rock phosphate (RP) is mined in Africa and was available in Nigeria and Kenya, but is slower to release its P.

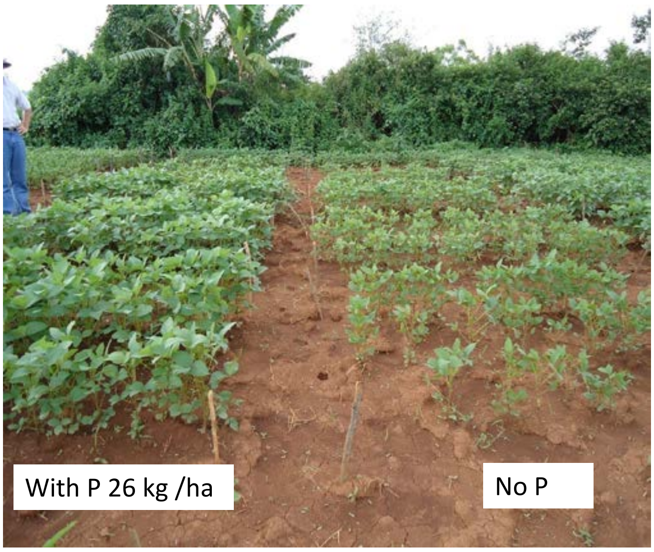


Figure 4.2: Response of soyabean to modest application of phosphorus was the first approach to better managing BNF.

Yield increase following P application was recorded across the impact Zones in 60% of trials, with yield increases of 5-50% depending on P-source, the legume and the site (e.g. Figure 4.2). TSP and SSP always provided better response than RP on moderate acidic to neutral soils but RP gave comparable yields to TSP and SSP on acidic soils (e.g. Figure 4.3). No attempt was made to study the residual effect of RP, but literature reports high residual RP effect on subsequent crops (e.g. Sanginga and Woomer, 2009).

Table 4.3: Soyabean response to inoculation, P addition and both at selected sites in four countries.

Country	Site	No inputs	Inoculant (seed)	P applied	Inoculant and P
Rwanda	Musambira	893	1198	1336	1336
Kenya	Migori	1693	2136	2365	2676
Ghana	Nyankpla	2067	2173	2856	3055
DR Congo	Mushinga	2204	3031	2667	3055

Application of inoculants in conjunction with P greatly increased soyabean yields at many sites (Table 4.3) with an overall increase of 47% compared to no-inoculated control. Similar results were reported from the dissemination trials in Nigeria, Ghana and DR Congo (Franke and Ronner, 2013). Response of beans offer less promise but studies into management approaches that increase combined response continue. More studies are also warranted to assess inoculant delivery strategies that further enhance inoculation response through better inoculant strains, optimal doses and best placement.

Different sites vary in their response to P source as illustrated by Figure 4.3 where cowpea variety Danila is grown at three locations in northern Nigeria. At Soba all sources performed equally, but rock P was less efficient at the other two locations. Cowpea variety Danila further responded to Agrol, a micronutrient concentrate, at Albasu. Rock P is the least expensive of these P sources but must be applied with prior knowledge of its effectiveness.

4.2.2 Non-responsive soils

Soils not responding to P application were encountered in 40% of the study sites and grouped as non-responsive. These areas include sandy, nutrient-depleted soils in west Kenya, Zimbabwe and Malawi; highly weathered soils in northern Rwanda and adjacent DR Congo; and drought prone savannahs of Ghana and Nigeria. Greenhouse diagnosis identified limiting nutrients in many non-responsive soils to be potassium, magnesium and zinc, leading to the formulation of blended fertilizers to meet these multiple nutrient limitations (van der Starre, 2012; Seitz, 2013; Keino, 2014*). Some sandy soils required the addition of organic inputs. Soils with high infestation of disease and nematodes also caused 'non-responsiveness' of bean in west Kenya and must be addressed through integrated pest and disease management strategies.

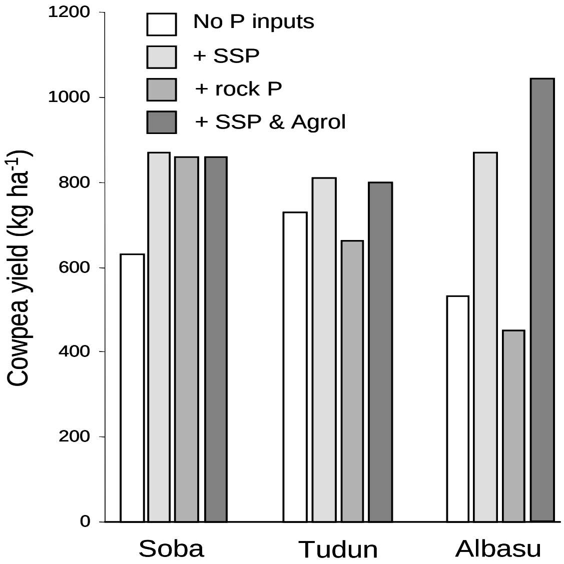


Figure 4.3: Response of cowpea cv. Danila to different sources of P at three sites in northern Nigeria. Agrol is a source of micronutrients with a strong application effect at one of the sites.

4.2.3 Specialized fertiliser blending

Crops receiving P-fertilizer alone at the non-responsive sites displayed a range foliar deficiency symptoms, including general chlorosis, marginal necrosis and interveinal chlorosis that corresponded to greenhouse diagnosis. First, potassium fertilizer (KCl) was included with P but this proved only partly effective. A specialised fertilizer blend of 7 parts TSP, 7 parts SSP, 5 parts MOP, 1 part magnesium sulphate and 0.1% zinc was composed and compared to SSP alone. This blend performed well and was later named Sympal (0:23:15 plus 10% Ca, 4% S, 1% Mg and 0.1% Zn). When tested on bean and soyabean in problem soils of DR Congo, Kenya and Rwanda, it improved yields by 6% to 15% despite being less expensive compared to most P fertilizers. MEA Fertiliser Ltd. (Kenya) commercialized Sympal using a four-channel blender and found ready market demand, selling about 1700 tons as 1, 2, 10 and 50 kg bags (Figure 4.4). This fertilizer blend is available and widely marketed alongside grain legume seeds and inoculant in west Kenya.

Figure 4.4: Fertilizer blending of Sympal at the MEA Ltd. factory in Nakuru, Kenya.

4.2.4 Other management considerations

Several other management considerations were addressed for inclusion into dissemination tools and extension messages including optimal plant spacing, pest and disease management, crop rotation and staking systems of climbing bean with key findings as follows:

Figure 4.5: Soyabean intercropped with dwarf sorghum. Strong markets exist for both crops.

- Spacing trials were conducted on soyabean revealed that 45 cm between rows and 5 cm within row is an optimum spacing for soyabean in East and Central Africa. This spacing was recommended practice in Malawi and Zimbabwe but lower densities were planted in other countries.
- Rotation of grain legumes and maize emerged as a standard practice. Rotating maize after soyabean typically results in yield increase of between 0.5 to a 1.3 t ha^{-1} depending on soil fertility. In some cases, planting grain legumes the first season prevents maize failure the next. Crop rotation also reduces pressure of pest and disease.
- Intercropping soyabean with maize is difficult as this legume performs poorly as a shaded understorey. Strip cropping with several alternate rows of each crop is one solution. Another is to grow soyabean in alternate rows with upland rice or dwarf sorghum (Figure 4.5). Groundnut behaves similarly to soyabean but beans and cowpea are more shade adapted.
- Fungicide controls Asian rust on soyabean, particularly on the more susceptible varieties, increasing yields by 13%. The use of pesticides is recommended on rust susceptible varieties with high or specialized market demand, but otherwise disease is best overcome by crop rotation and use of resistant varieties.
- Beans and cowpea often require control of insects including aphids, scales and thrips. The young leaves of these two crops are edible so care must be taken to avoid consumption if pesticides have been applied. Many farmers practice a system of over-planting beans and cowpea, and then thinning for use as green vegetables while then managing the remaining crop for grain using Integrated Pest Management.
- Groundnut is the best crop for combined grain and fodder production because the leaves remain green through harvest. Varieties with resistance to Rosette Virus are available.
- Staking climbing beans is a major challenge for small-scale farmers, particularly in more densely populated landscapes. Establishing permanent trellises is feasible for smaller fields, but others require temporary staking systems, with tripods being most efficient. Many farmers developed complex methods relying upon stakes, live trees, string and intercrops.

4.3 Forage legumes

Farmers' need for high quality fodder for cattle. goats and sheep provides an entry point for establishing herbaceous and tree forages (Baijukya and Giller, 2012). Livestock are important to small-scale farmers in terms of household nutrition, a means of savings, and production of manure for use in higher-value crops. These legumes can provide a major source of recyclable nitrogen inputs and is best stimulated through the increased availability of seed. N2Africa explored the promotion of multi-purpose forage legumes for intensive meat and milk production by first identifying which legumes have greater potential within key agro-ecosystems in Central, East, Southern and West Africa and then securing sufficient planting materials from both research and commercial channels for initial and farmer testing. In this way, improved lines of multipurpose forage legumes were made more widely available to farmers, with the perennial stands established for on-farm testing providing a practical demonstration and a source of seed into the future.

In Kenya, DR Congo and Rwanda tree legumes *Calliandra callothysus*, *Leucaena pallida* and *Leucaena diversifolia* are preferred by farmers among the tested tree legumes whereas *Desmodium intortum and Macroptilium atropurpureum* emerged the most preferred herbaceous legumes (Figure 4.6). The selection criteria were 'fast growing', 'adaptation to poor soil' and 'ability to grow in mixtures with Elephant grass', the common fodder grass found in the region. In Zimbabwe *Acacia angustissima*, *Cajanus cajan* are the most preferred tree legumes whereas *Lablab purpureus*, *Crotalaria juncea* and *Crotalaria ochroleuca* are most preferred forage legumes. In Rwanda and Kenya, promotion of tree legumes was done through D&D partners as future source of staking materials for climbing bean.

Figure 4.6: A potent forage combination: *Macroptilium atropurpureum* (Siratro) growing in mixture with elephant grass in Cyabingo, northern Rwanda.

4.4 **System productivity, benefits and trade-offs**

These stepwise advances in Legume Agronomy lead to greater understanding of their contributions to system productivity, grain legume enterprise and farm livelihoods. First, household impacts from specific BNF interventions were assessed in terms of costs and net benefits, and used to validate best-fit practices (Woomer, 2013). Then the relative contributions of each BNF intervention type; inoculation with rhizobia, substitution of improved varieties, and better management of soil fertility were described within major agro-ecological zones. Finally, the potential roles of several nitrogen-fixing legumes within specific farming systems, agro-ecologies and market opportunities in Africa were described in both technical and popular terms so BNF technology interventions may be better targeted within future rural development programs (Franke *et al.*, 2013).

Many of the issues related to non-responsiveness to management are captured in Figure 4.7 where net returns strongly vary with management decisions e.g. at Butere, west Kenya. This location is one of the first to adopt widespread soyabean cultivation of the culinary industry standard variety (SB 19) and the subsequent proliferation of native or introduced rhizobia, and invasion of Asian rust. Large economic returns are not realized with SB 19, which is extremely susceptible to rust, without investing in the Sympal fertilizer blend. Switching

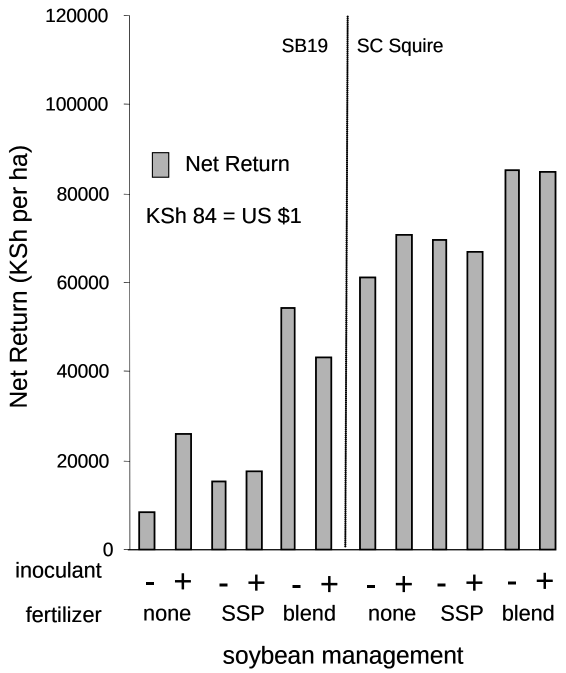


Figure 4.7: Management response testing of soyabean in Butere, west Kenya illustrate the economic benefits of varietal choice and more complete fertilization. (KSh 85 = $1).

over to SC Saga offers immediate solution, even though this commodity-type soyabean commands a lower price in Kenya. Again, a response to more complete fertilization is achieved, but the native rhizobial population appears sufficient to preclude inoculation response.

While varieties and farm inputs were usually evaluated separately, some research campaigns in Kenya, Mozambique, Nigeria and Rwanda combined the two factors at several sites and over repeated seasons that allowed for their relative contributions to be described. For example in Rwanda the phosphorus x inoculant interaction was examined for six cultivars, including the farmer's common variety Peka 6, in three agro-ecological zones over two seasons, allowing for the effects of varietal substitution (VSI), inoculation response (IRI) and phosphorus addition (PAI) to be indexed relative to no change scenarios (Table 4.4). Improved varieties offered reliable yield improvement across all input strategies, as did seed inoculation with rhizobia across all varieties and P applications, but addition of P was not effective, even in conjunction with inoculants. An overall management index (MPI) suggests that the best practices improves yield by 46% to 61%.

Table 4.4: Stepwise improvement of soyabean production in Rwanda involves varietal selection, inoculation and fertilization.[1]

Choose Variety[2]	Inoculate seed	Add phosphorus	Yield kg ha^{-1}	VRI	IRI	PAI	MPI
				------------ indices[3] ------------			
Farmer	no	no	1044	1.00	1.00	1.00	1.00
Improved	no	no	1329	1.27	1.00	1.00	1.27
Farmer	no	yes	882	1.00	1.00	0.85	0.85
Improved	no	yes	1491	1.69	1.00	1.13	1.43
Farmer	yes	no	1196	1.00	1.15	1.00	1.15
Improved	yes	no	1678	1.40	1.26	1.00	1.61
Farmer	yes	yes	1060	1.00	1.20	0.89	1.02
Improved	yes	yes	1528	1.44	1.03	0.92	1.46

[1] Based on 3 sites and 2 seasons receiving USDA 110 and SSP where indicated.
[2] Farmer variety = Pico 6, improved varieties include 5 TGx and SeedCo lines.
[3] Indices include Variety Substitution (VS), Inoculation Response (IR), Phosphorus Addition (PA) and overall Management Potential (MP).

Table 4.5: Baseline yield, responses to management and improved yields of soyabeans observed across four N2Africa countries over many sites and years in on-farm trials.

Country	Baseline yield kg ha^{-1}	Inoculant	Variety	Fertilizer	Management	Final yield kg soyabean ha^{-1}
		------------------ response index ---------------				
Kenya	526 (±19)	1.28	1.48	1.63	3.17	1666 (±80)
Rwanda	1044 (±149)	1.16	1.45	0.94	1.46	1528 (±103)
Nigeria	1221 (±65)	0.97	1.68	1.59	1.23	1705 (±177)
Mozambique	2328 (±64)	1.13	1.04	1.02	1.40	2857 (±81)
mean	1280 (±74)	1.14	1.41	1.30	1.81	1939 (±110)

These indices may then be compared across countries (Table 4.5) allowing for conclusions concerning management and yield improvement of soyabean. Overall, yields are improved by varietal selection, fertilizer addition and inoculation in descending order resulting in an overall improvement of 81%. This hierarchy of interventions is not constant across countries and their representative agro-ecological zones. In the highly weathered soils of Kenya's Lake Victoria Basin and adjacent midlands, addition of fertilizer has a large effect, but not in the Equatorial Highlands of Rwanda with its younger soils of volcanic origin. Improved varietal selection over older TGx lines and making P fertilizers more available have large effects in Nigeria, probably because of decades of crop breeding targeting more promiscuous nodulation by native rhizobia. This contrasts with Mozambique where improved varieties respond strongly to inoculants. Indeed, all three elements of improved production, inoculation, varietal substitution and fertilizer addition, are important, but vary between zones and across agricultural landscape, suggesting that site-specific technologies are required.

The many benefits of advancing grain legume enterprise and BNF are described throughout this report. Briefly, by intensifying legume production, small-scale African farmers are better able to feed their families, generate income and maintain soil fertility. Trade-offs exist, particularly toward crop selection as many cereals and root crops are more productive and under some conditions more profitable in the short term. Grain legumes may be grown both in rotation and as intercrops. In the case of rotation, residual nitrogen in legume residues and roots is available to subsequent crops, boosting their yields and reducing dependency on N-fertilizers. Rotation also disrupts pest and disease cycles. In general, grain legumes are best rotated every other to every fourth crop, Grain legumes may also be grown as intercrops, usually as an understory. Beans and cowpeas perform well under partially shaded conditions, but options are available to intercrop groundnut and soyabean as well depending upon choice of companion crops and spacing. The adoption of grain legumes has a strong component of site specificity that when applied results in several proven roles for these legumes.

4.5 Proven roles of legumes in farming households

Project findings documented the roles of several grain and forage legumes in both technical and popular terms so they may be better targeted within future rural development programs. These legumes are considered in both an economic and agro-ecological context as follows:

4.5.1 Soyabean in the East African midlands

Soyabean enterprise was widely adopted in west Kenya, particularly the culinary varieties (high protein: lower oil) introduced from IITA (Figure 4.8). Foremost among these varieties is SB 19 (TGx1740-2F), a cream-colored, indeterminately flowering but fast maturing variety used in food processing. This variety performs best at high plant populations (60 kg seed ha^{-1}), produces about 28 seeds per plant and is grown in rotation with maize-bean intercrops. It is sometimes grown as an intercrop of dwarf sorghum or upland rice, but performs poorly in the maize understorey. Its production is supported by the increasing availability of legume inoculants and specially blended fertilizers, and the joint establishment of marketing collection points by farmer groups and Promasidor Ltd., its main buyer. SB 19 is small-seeded (0.13 g seed) and susceptible to Asian rust but when grown following best practice economic returns averaging \$653 ha^{-1} may be achieved.

Figure 4.8: This farmer in Bungoma, west Kenya received 1 kg of SB 19 in one season, and used the harvest to plant 0.5 ha the next.

4.5.2 BNF technology transfer to commercial French bean and Sugar pea growers in Central Kenya

One mark of an appropriate technology is when it is transferred to other places and crops. This is the case with BIOFIX inoculant and Sympal fertilizer strategies developed for soyabean in west Kenya but then adopted by French bean and Sugar pea growers in the Central Highlands (Figure 4.9). Originally, these crops were first grown with fertilizer nitrogen only, but inoculants permitted these growers to reduce their nitrogen application while still meeting the high industry standards for export to Europe and the Middle East. This adoption occurred without facilitation by N2Africa, rather our partner MEA Ltd. encouraged the producer associations to test the N2Africa production package for new crops and agro-ecologies.

Figure 4.9: Farmers growing French bean and Sugar peas in Central Kenya spontaneously adopted the BIOFIX-Sympal package developed for soyabean in west Kenya by N2Africa.

4.5.3 Climbing bean in the East and Central African highlands

Bean is widely grown and a preferred food but its availability is greatly reduced by chronic pests and disease resulting in low yields. Bush bean grown as maize understorey is most affected, and its poor growth usually does not offer benefits of net nitrogen gains even though it nodulates with native rhizobia. Climbing beans, first introduced by CIAT and later incorporated into national programs, offers a breakthrough with yields of up to 4 t ha^{-1} and net returns of \$1080. These benefits come at a cost, however, as this crop must be staked and requires skills in pest management. In Kenya climbing bean Tamu with its very large seed and reduced susceptibility to root rot and aphids (Figure 4.10), has proven to be a suitable and well-adapted variety. Other varieties have proven to be suitable for other areas (Table 4.2).

Figure 4.10: Cultivating climbing bean requires staking and pest management, but offers much higher returns than bush beans.

4.5.4 **Calliandra as a fodder tree in milk and meat production**

While the main focus within N2Africa was upon its four target grain legumes; bean, cowpea, groundnut and soyabeans, addition attention was paid to promising tree and fodder legumes where they offered promise for ready incorporation into smallholder farming systems. One example of this is the use of *Calliandra calothrysus* as a multipurpose tree in eastern Congo, Kenya and Rwanda. This fast-growing tree has high rates of BNF that in turn offer protein-rich fodder to livestock and stakes for climbing bean. Planted on the contour it reduces soil erosion or established around field and farm boundaries it forms a live fence (Figure 4.11). This tree is best established as a transplanted seedling, offering opportunity for tree nursery enterprise.

Figure 4.11: Calliandra established along a farm boundary in eastern DR Congo.

4.5.5 **Groundnut production in Southern Africa**

Groundnut offers potential to become a major crop in Southern Africa because of its multiple uses, steady demand and high price ($1.00 to $1.30 kg^{-1}). This crop has a strong taproot and is able to evade short-term drought. In the past groundnut rosette virus posed a serious problem to growers but new varieties, such as the ICGV series from the offer strong resistance. It is best suited to sandy loams, soils very common in Southern Africa, but requires calcium in the soil for successful pod fill. Gypsum offers an inexpensive source of this calcium. Groundnuts are associated with rhizobia common to African soils, inoculation is not currently recommended and BNF in well-managed systems exceeds 60 kg N ha^{-1}. The leaves and stems of groundnut are particularly important to livestock because foliage remains green through seed ripening, so groundnut provides nutritious hay. Two issues are central to the large-scale development of groundnut as an export commodity, overcoming yield gaps and the management of aflatoxins to industry standards. N2Africa worked closely with its outreach partners such as IKURU in Mozambique (Figure 4.12) to assist in the development of this commodity for export.

Figure 4.12: Shareholders of the IKURU Cooperative in Mozambique growing groundnut as a cash crop.

4.5.6 **Intensification of cowpea in West Africa**

Cowpea is an important crop to household food and nutritional security because its leaves, young pods and grains are edible and nutritious. It has strong demand in local markets and commands a good price (\$0.80 to \$1.20 kg^{-1}). The project sought to advance cowpea enterprise and biological nitrogen fixation in four countries and found greatest success in Nigeria where yields among participating farm households were increased by 41% worth \$320 ha^{-1} (Figure 4.13). The leaves, pods and grain contain 36%, 33% and 26% protein, respectively, and this crop provides some of the first harvest in the hunger season. Cowpea is readily nodulated by native rhizobia, and inoculation is not required, but under proper management it can fix more than 75 kg N ha^{-1}. Cowpea responds to P-fertilizers and micronutrient application in the Northern Guinea savanna is often attacked by insects, requiring control with insecticides. One useful practice is to over-plant cowpea, harvest part of the stand as whole plants for vegetables and then initiate control over the remaining crop.

Figure 4.13: A new cowpea variety IT97K-499-35 performed well in Northern Nigeria.

5 Harnessing Rhizobia and Advancing Legume Inoculants

Rhizobiology is the study, and useful application, of root nodule bacteria associated with symbiotic legumes. The goals of the project's Rhizobiology activities were to select superior rhizobia strains for enhanced BNF and develop inoculant production capacity in sub-Saharan Africa, including among private sector partners. N2Africa has revitalized Rhizobiology in its eight countries and proven its useful application. To achieve this success, it was important to quickly develop a series of field and laboratory protocols related to bio-prospecting (Woomer *et al.*, 2011) and isolation of rhizobial strains (Bala *et al.*, 2010), and to train a cadre of technicians and young scientists (Koala *et al.*, 2011). This capacity building then allowed for conducting Need-to-Inoculate tests, collecting African rhizobia and identifying elite strains, insight into the better formulation of legume inoculants and expanded inoculant production capacity in sub-Saharan Africa.

5.1 Need-to-Inoculate tests

From the project's onset we sought to assess the need-to-inoculate the target grain legumes. Experience suggests that two of those legumes, bean and soyabean, are more specific in their association with rhizobia and more likely to respond to inoculation. Two approaches were taken to assess likely inoculation response: (1) to determine the most probable number of rhizobium cells, whereby soils are serially diluted, then applied to the root systems of host legumes and presence or absence of nodulation is observed (the Most Probable Number determination, Woomer *et al.*, 2011), or alternatively (2) to conduct the Need-to-Inoculate test where host legumes are grown in potted soil receiving basal fertilizers (not including N) alone or either inoculated with rhizobia or receiving mineral N. Results of the MPN procedure may be interpreted in terms of likely inoculation response. Legumes on soils with fewer native rhizobia (<50-300 rhizobia per g soil) are more likely to respond to inoculation, as a large natural background of population of rhizobia may reduce the need for applied inoculant strains. The difficulty in executing MPN is its need for sanitary, cooler growing conditions. Four countries opted for this approach (Table 5.1).

Table 5.1: Most Probable Number determinations conducted in four countries and with two legume hosts (SEM in parenthesis).

Country	Legume host	n	MPN rhizobia g soil^{-1}	Compliance *p*
DR Congo	bean	17	9664 (±7200)	0.04
DR Congo	soyabean	17	57 (±34)	0.14
Ghana	soyabean	18	70 (±14)	0.13
Kenya	bean	25	141 (±53)	0.41
Nigeria	soyabean	7	1808 (±479)	na
Overall		84	1813	0.18

5.1.1 Plant infection counts

In all, 201 MPNs were conducted using common bean or soyabean as hosts. This falls short of the original target of 50 MPNs per country. Some difficulty was experienced in this procedure, particularly the unsuitability of greenhouses for growth pouch culture. The first 24 assays using soyabean in Kenya were rejected on a statistical basis, as were all 23 assays from Malawi. Nonetheless, useful findings from MPNs were obtained (Table 5.1). In DR Congo it is clear that soyabean is more likely to respond to inoculation than bean, a prediction that was later confirmed through agronomic trials. Results from Ghana and Kenya also indicate likely response by soyabean. A test of compliance with assumptions underlying MPN, that one single rhizobium results in nodule formation, is built into the range of transition from entirely positive to entirely negative results (Woomer *et al.*, 2011). In this way, extremely unlikely results (e.g. $P<0.01$) may be rejected. The greater usefulness is from the interpretation of specific MPN results. In the case of Ghana, a wide range of MPN results (Figure 5.1) indicate that some sites are far more likely to respond to inoculation than others.

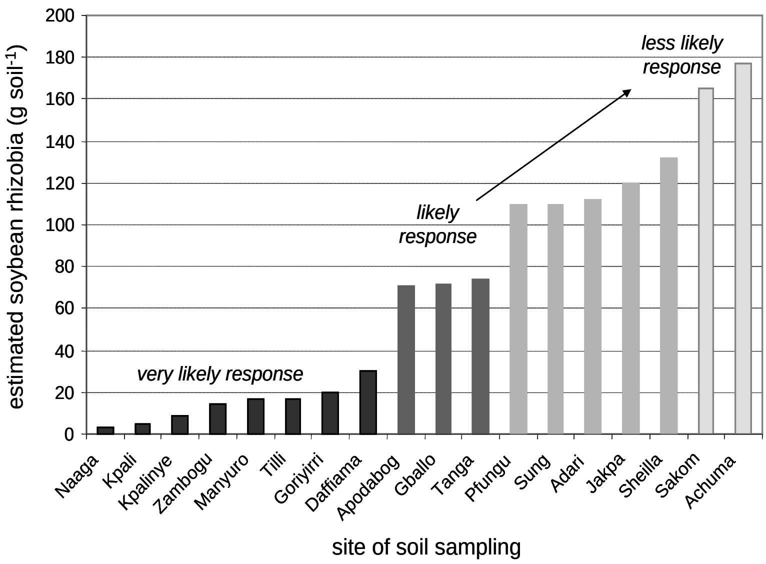


Figure 5.1: MPN results using soyabean from 18 sites in Ghana indicate a wide range in native rhizobia.

5.1.2 Plant assay

An alternative approach to predicting inoculation response is through greenhouse testing of potted soils. When difficulties in conducting MPNs first emerged, supplemental protocol for Need-to-Inoculate Tests was designed (Bala, personal communication). A need-to-inoculate trial utilizes various soil fertility treatments to determine yield under non-inoculated, inoculated and N-fertilized management. The test is conducted in the greenhouse using potted soil. All treatments receive basal dressings of phosphorus and potassium. Differences between the N-fertilized and non-fertilized treatment indicates N response (or when used as ratio the Nitrogen Responsiveness Index - NRI - of that soil). Differences between inoculated and non-inoculated treatments indicate response to inoculation (as ratio it gives the Inoculant Responsiveness Index – IRI). Comparison between the inoculated and N-fertilized treatment provides information on the degree to which inoculation is able to satisfy the nitrogen demand. Soils fall into four categories based upon their combined N-responsiveness and inoculant-responsiveness indices. Malawi and Nigeria opted for this approach and conducted the tests on a large number of soils. Figure 5.2 presents the data from 23 farms in Malawi (three replications per farm/location; observations from four farms were rejected). Overall 63% of the sites respond to inoculation (that show an IRI of higher than 1.05; taking 5% of the control yield as error margin). 17% give negative response (IRI < 0.95), while for 20% there is no difference. In 52% of the cases there is a positive response to N application (NRI > 1.05). The Need-to-Inoculate tests in Malawi suggest a 16% response to inoculation in cases of a positive response (average IRI for cases where

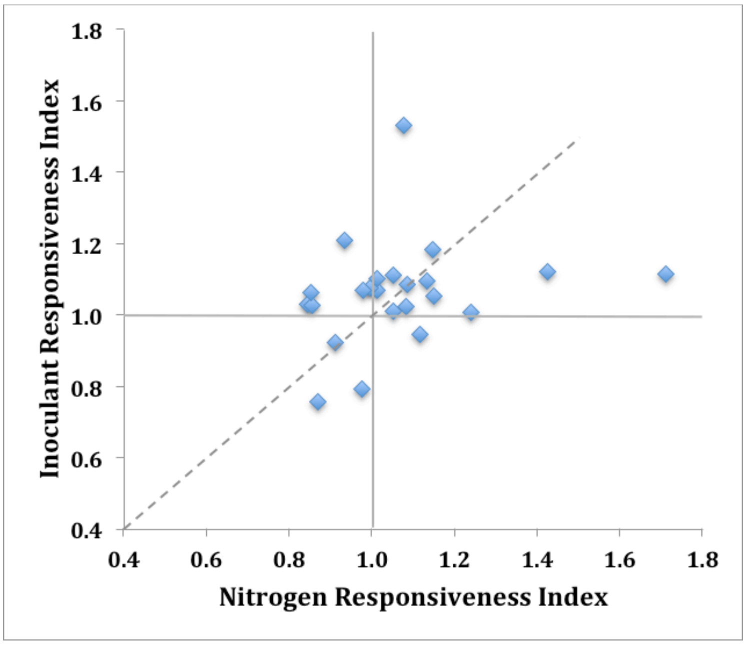


Figure 5.2: Results from greenhouse Need-to-Inoculate trials fall into four categories with 52% indicating a potential response to soyabean inoculation in Malawi.

IRI is > 1.05). This does not predict yield response to inoculation in the field. On-farm measurements across Malawi indicated a 37% yield response under field conditions.

Despite the limitations of both assays, the findings from them can lead to recommendations on where different degrees of legume inoculation response may be further studied in agronomic trials. This, however, requires adequate planning and sequencing of activities between the Rhizobiology and Legume Agronomy teams. As yet, N2Africa has not tested widely the Need-to-Inoculate predictions in the field or Thies' hypothesis that MPN assessment should indicate less than 1 0 Rhizobia cells per g of soil to warrant response to inoculation. A first attempt was made in Ethiopia with chickpea although MPNs were less than 10 cells per g of soil in all cases and yet strong response to inoculation was not always observed (Aliyi, 2013; Fig. 9.1). N2Africa research laboratories are now able to perform and interpret these tests. We need further research to understand patterns in background populations and identify the factors that influence response to inoculation. Only then will we be able to direct, extension workers and inoculant distributors to areas where inoculation response is most likely and direct scientist on research to improve inoculants.

5.2 Collecting African rhizobia and identifying elite strains

An important goal of the N2Africa project is to discover new and better strains of rhizobia for use in legume inoculants. This pursuit entails the collection of isolates, strain characterization, assessment of symbiotic capacity and comparison to strains currently included within inoculants. The process of bio-prospecting for rhizobia and their detailed characterization and preservation is somewhat arduous, and efforts by N2Africa was largely focused upon target grain legumes and their close relatives. Isolates were prepared as described by Bala (2011).

Table 5.2: Parameters included on the N2Africa Rhizobium Database.

Source country: NAC = DRC, NAG = Ghana, NAK = Kenya, NAM = Malawi, NAQ = Mozambique, NAN = Nigeria, NAR = Rwanda, NAZ = Zimbabwe
Entry: strain number in chronological order
Contributor: Organization holding isolate
Alternate Code: strain designation of contributing organization
Longitude and Latitude
Host Sub-family: M = Mimosoideae, P = Papilionoideae
Host Tribe: taxonomic group of host legume at Tribe level
Host Genus: Original host legume genus
Host Species: Original host legume species
YMA Growth rate: S = slow, I = intermediate, F = fast
CR YMA: colony characteristics on Congo Red
BTB YMA: Reaction on bromothymol blue
Test Host: legume host used in effectiveness testing
Reference: reference rhizobium strain in effectiveness testing
Performance: ratio of isolate to reference strain
GH95: is isolate among the top 5% in greenhouse, 0 = no, 1 = yes
F98: is strain among the top 2% in field testing, 0 = no, 1 = yes
Candidate: candidate elite strain for inoculant production, 0 = no, 1 = yes

A MS Excel database is developed to compile the results from bio-prospecting, characterization and effectiveness screening of rhizobia among the collaborators. It has 16 descriptors (Table 5.2) that cover the isolate origin, including taxonomic position of host legume, performance on diagnostic media and in effectiveness tests, and its eligibility as a candidate elite strain.

To date, seven countries have entered information on 1360 isolates into the database with another 84 to be entered (1437 total). This is 72% of the project target of 2000 isolates (or 250 per country). Legume host taxonomy ranges from 1 to 9 tribes, 2 to 20 genera and 2 to 27 species per country (Table 5.3). This taxonomic spread reflects large differences in sampling strategy, such as Zimbabwe that sampled cultivated fields of one or two target grain legume (bean and soyabean; data not presented) and DR Congo and Kenya that sampled all cultivated and natural legume communities encountered across a wide range of agro-ecologies. Rwanda started collecting from both cultivated fields and wild communities, but then narrowed its search upon two hosts (bean and soyabean). Nigeria not only sampled its three target legumes, but also Bambara groundnut (*Vigna subterranea*), an important indigenous food legume. Malawi included *Desmodium* spp. in its sampling strategy. Ghana sampled some legumes belonging to the *Mimosoideae* and *Caesalpinoideae* sub-families as well. More detail on bio-prospecting and the N2Africa Rhizobium Database appears in Woomer *et al.* (2013).

Table 5.3: Entries and host taxonomy of isolates entered into the N2Africa Rhizobium Database.

Country	Entries	Tribes	Genera	Species
DR Congo	104	11	16	25
Ghana	168	5	7	8
Kenya	387	9	20	27
Malawi	170	2	4	6
Nigeria	250	2	3	4
Rwanda	252	8	12	14
Zimbabwe	29	1	2	2

5.3 **Effectiveness testing and identification of elite strains**

5.3.1 **Symbiotic effectiveness assay**

Effectiveness testing of the collected strains involves greenhouse trials where host legumes are raised in rhizobium-free media and then test cultures applied, and growth response measured. These trials require non-inoculated controls and the results are best compared to current industry standards. Two basic growth systems were employed in the project, Leonard jars or pots containing vermiculite or sand. In general, smaller units suffer less contamination but restrict plant growth while larger units must be carefully protected from contaminants and permit much larger test plants that allow for greater differentiation of test isolates. Effectiveness testing was performed on both soyabean and bean using as many as 100 test isolates at a time, depending upon clean greenhouse space and the availability of materials. The aim is to identify which isolates outperform industry standards. The results of effectiveness testing at the University of Nairobi MIRCEN indicates how isolates are assigned to four categories based upon their relationship to the non-inoculated control and established industry standard USDA 110 (Figure 5.3). The most effective isolates are carried to the next stage of testing.

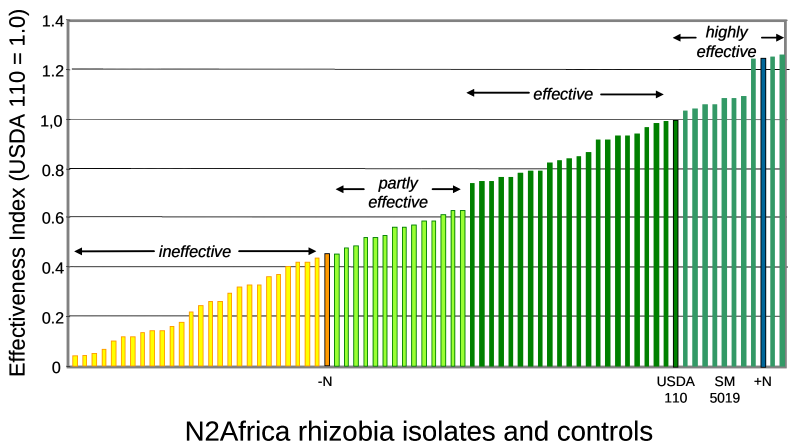


Figure 5.3: Effectiveness of 80 isolates nodulating soyabean, grouped into four categories from 'ineffective' to 'highly effective' and including three elite strains.

5.3.2 Competition assay

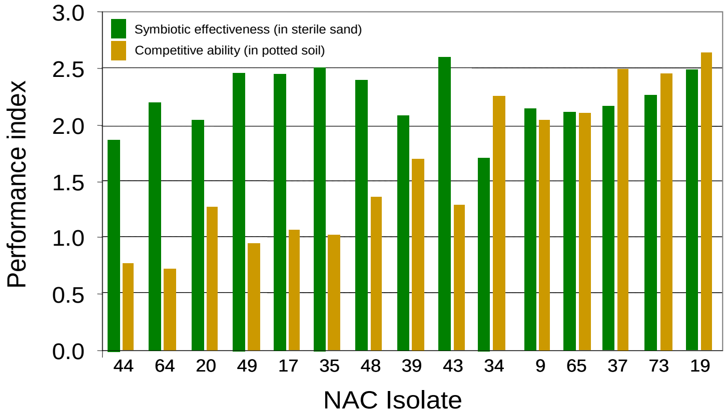


Figure 5.5: Symbiotic and competitive abilities of selected NAC isolates on soyabean under greenhouse conditions.

The competitive ability of the most effective isolates was next tested under representative soil conditions. We refer to these as 'competition assay' because effectiveness of the strain to be tested has been proven already, though strictly speaking this test shows competitive ability as well as effectiveness in potted soil. Host legumes were planted into potted test soil in the greenhouse, and then test isolates applied as broth. In this case, the native rhizobia serves as the baseline control so it is important to select test soil based upon MPN results (e.g. between 50 to 300 indigenous rhizobia per g soil). Test units that outperform the non-inoculated control soil are considered to be competitive and those that do not are less competitive. The best isolates, those that are both highly effective and competitive are considered to be candidate elite strains used in later field-testing. The strength of this approach is illustrated through results from DR Congo where 15 highly effective isolates for soyabean are identified and then evaluated in potted soil (Figure 5.5). The performance index is based upon the ratio of the test isolate to industry standard in absence of a rhizobial background, while competitive ability compares strain effectiveness to native rhizobia in a non-sterile potted soil. This approach permitted the isolates to be separated into two categories, highly effective/less competitive and highly effective/competitive, with five isolates performing very well in both assays. Note that all these test isolates outperformed USDA 110 in effectiveness.

5.3.3 Field testing

Finally, the candidate elite strains are tested in the field under farmer conditions. Only Kenya, Nigeria and Zimbabwe reached this stage of isolate testing. Several useful experimental approaches were employed in this effort. The field trials include industry standard strains, local isolates, non-inoculated controls and managements receiving fertilizer nitrogen. Field work was conducted in N-deficient soils and, where possible, an additional high C:N material (e.g. sugar cane bagasse) was applied to reduce N mineralization. For seed inoculation with the local candidate elite strains, the N2Africa laboratories must produce their own experimental inoculants. Different strains were well separated by non-inoculated boundary rows, resulting in a "rolling effect" of healthy green and smaller chlorotic rows (Figure 5.4).

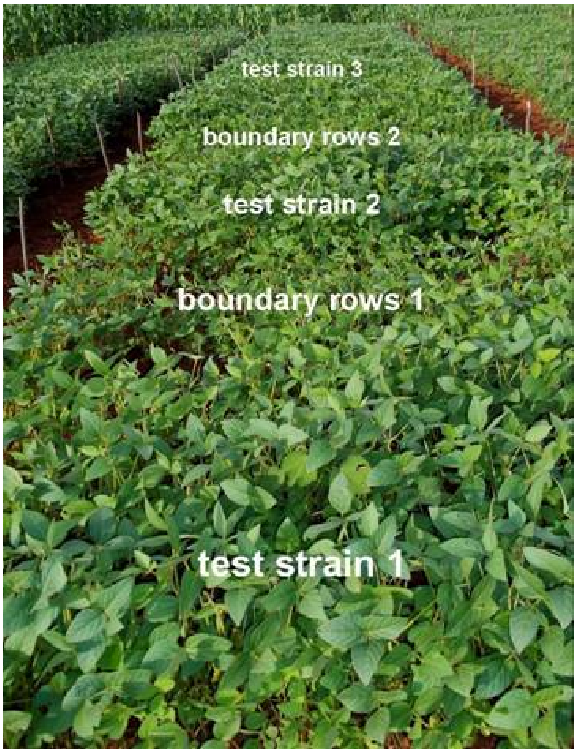


Figure 5.4: The rolling effect achieved by separating elite isolates with non-inoculated boundary rows under N-deficient soil conditions.

Results from one field trial in west Kenya clearly illustrate the strong performance of isolates forwarded as N2Africa elite strains (Table 5.4). Note how modest yield increases result in large partial returns to inoculation because inoculants are inexpensive compared to the value of the grain they produce.

Table 5.4: Grain yield by soyabean under different nitrogen managements in west Kenya.

N source	------ SB 19 ------	
	grain yield	partial return[a]
	kg ha^{-1}	\$ per \$
Non-inoculated	1057	n.a.
USDA 110	1129	3.9
NAK 115	1153	5.2
NAK 135	1212	8.3
N-fertilizer applied	1299	0.7
NAK 84	1339	15.1
NAK 128	1462	21.7

[a] Partial return calculated as increased soyabean value/cost of N source with soyabean valued at \$0.613 kg^{-1}, inoculant at \$11.40 ha^{-1} and CAN-N at \$2.38 kg^{-1}

5.3.4 Recommended elite strains

The empirical, stepwise approach to strain selection used by N2Africa is partially successful in that it started with a large number of test isolates and systematically reduced them to a few, highly effective and competitive strains (Woomer *et al.*, 2013). Originally, N2Africa sought to identify 40 strains of elite, well-characterized rhizobia and make them available to the worldwide research and inoculant community. Furthermore, five superior strains of rhizobia would become mass-produced by legume inoculant manufacturers resulting in greater returns to investment in inoculation technology by African farmers. To date, 13 isolates from the N2Africa are recommended for advanced testing on climbing bean (1), bean (4) and soyabean (8) and ready for distribution to interested parties (Table 5.5). Part of this success is due to reliance upon larger growth units in greenhouse experiments, and greenhouse sanitation that permits these units not to become contaminated. Another component is comprehensive bio-prospecting throughout many countries, and the additional testing of strains for competitive ability in potted soil. One strong indicator of our success is the performance of our best isolates compared to long-time industry standards USDA 110 and CIAT 899. In one case, none of 53 locally obtained test isolates from Ghana outperformed USDA 110 but in other countries (e.g. DR Congo, Kenya and Nigeria) several more effective strains were readily identified. Bio-prospecting for superior African rhizobia should continue and collected isolates further characterized. The best isolates will be brought into a colledction for further comparison, long-term storage and release to other interested parties.

Table 5.5: Candidate elite strains emerging from N2Africa bio-prospecting followed by effectiveness, competition and field testing.

Climbing bean: NAK 67

Common bean: NAK 45, NAK 104, NAZ 18, NAZ 23

Soyabean: NAC 19, NAC 73, NAK 84, NAK 128, NAN 109, NAN 177, NAZ 21, NAZ 25

5.4 Formulating improved inoculant

Practical goals of the project are to reduce the cost of inoculant manufacture and to improve inoculant quality. The N2Africa project examined cost effective inoculant production methods including fermentation technologies, carrier selection, inoculant formulation and enhanced shelf life. These advances were made in terms of recognizing constraints to current production and offering solutions to them. A few candidate carriers were examined but none were as good as peat. Testing of a peat source from DRC is ongoing. Protocols for quality assessment were agreed and adopted among N2Africa partners.

5.4.1 **Inoculant quality assurance**

Quality assurance within the project is designed to protect legume farmers from inferior products because one cannot judge an inoculant product at the time of purchase. Quality control involves testing inoculants for compliance with industry standards at time of their production and at various times of their shelf life. This evaluation includes the numbers of rhizobia, presence of pathogens and the amount within the package. The project was initially confronted by the lack of existing quality standards of legume inoculants. First, options for measuring quality were examined, and the drop plate technique on Congo Red YMA was identified as most expedient (Bala, 2011), and training in this and other techniques offered (Koala *et al.*, 2011). A minimum of 1 x 10^9 rhizobia per gram of inoculant was adopted. Table 5.6 presents the results of inoculant quality monitoring of BIOFIX over time. While the numbers of rhizobia satisfied requirements, the number of contaminants was already too high at production stage and further increased during storage. Finally, how quality control programs should be conducted was differentiated for countries that produce inoculants and those that rely upon periodic importation. Because the quality of any product is the responsibility of the manufacturer, internal quality control practice was emphasized as equally important within MEA Ltd. and SPRL, the producers in Kenya and Zimbabwe, respectively. One challenge involves the design and implementation of routine quality control procedures that permitted inferior batches to be intercepted before they were released to supply chains.

Table 5.6: BIOFIX inoculant quality over six month intervals in Kenya (CV in parentheses)[1].

Recovery location	expiry month	Rhizobia x 10^9 g^{-1}	Contaminants x 10^6 g^{-1}
Factory curing shelf	-6	7.1 (24%)	2.4 (36%)
Stockist refrigerator	-1	3.9 (33%)	98 (23%)
Stockist back room	+6	2.7 (88%)	53 (27%)
Stockist back room[3]	+12	2.6 (14%)	123 (9%)

[1] Inoculants with 6 month expiry date, quality targets of > 10^9 rhizobia and < 10^6 contaminants per gram.

There is need for establishment and better regulation of inoculant quality standards produced by the private or public sectors among the countries where N2Africa is active. Ghana and Kenya are in the process of adopting these standards. A common logo is proposed that bears three different grades of inoculant that reflect various competencies in manufacture (Figure 5.6). These grades span the standards of several countries and permit a stepwise approach that permits inoculant manufacturers to meet a minimal standard upon market entry and then recognize improvement in their product with time. Furthermore, shelf life may be based upon initial quality where fresh inoculants containing fewer rhizobia or more contaminants are assigned a shorter expiration interval. More information on the quality assurance of inoculants within N2Africa is available from milestone reports (Bala *et al.*, 2010; Woomer, 2013).

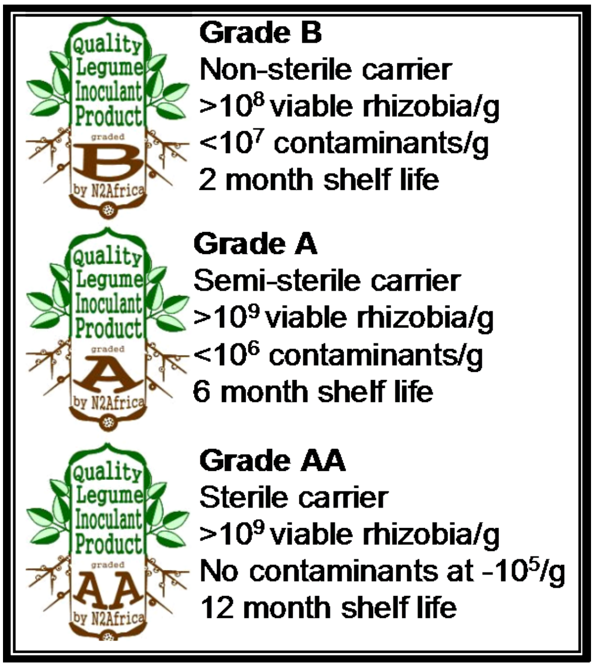


Figure 5.6: The proposed grades and quality standards of legume inoculants under the N2Africa universal logo

5.5 Expanded inoculant production capacity

The N2Africa project was founded on quantitative targets with regard to expanding inoculant supply. Short-term inoculant manufacturing capacity was to improve by at least 200,000 packets per year for use on 80,000 ha. Furthermore, private sector manufacture of inoculants was to be stimulated through the project and strategic alliances between private sector and research centres forged. During the project, inoculant production was initiated or enhanced in six countries, while two relied exclusively upon imports.

5.5.1 DR Congo

The Kalambo Agricultural Centre near Bukavu produces an experimental inoculant RHIZOFIX. Production started in August 2013 and it is made for use with bean or soyabean using strains USDA 2667 or USDA 110, respectively. It is packaged into 20 and 50 g using Walungu peat as a carrier and packets are injected with rhizobial broth by hand. The 50-g packet is intended for five kg of seed and is sold for about $2.20. The quality target is 1 x 10^9 cells per gram but quality control procedures are not yet finalized. Sugar is the recommended adhesive.

5.5.2 Ghana

The main inoculants used in Ghana were imported from Legume Technology (UK). This company was established in 2000 and manufactures a range of inoculants for legumes in both the agricultural and the home gardening markets. LegumeFix inoculants were imported as packages of 200 and 700 g intended for lots of 50 to 175 kg of seed. The product proved effective on soyabean although its large package size meant that inoculant packets were shared among farmers in groups. Ideally smaller packages would be made available to meet the requirements of an individual farmer.

5.5.3 Kenya

BIOFIX is a commercial legume inoculant manufactured and distributed by MEA Ltd. Separate inoculants are sold for six legumes including bean and soyabean using rhizobia strains obtained from MIRCEN. Commercial production started in late 2009 and reached 10.5 tons over the past year (2012). Package sizes range from 10 to 150 g with recommended doses of 10 g inoculant per kg seed. The carrier is filter mud from sugarcane pressing. Broth is produced in five-liter flasks connected in series with filtered air that is auto-injected and rotary mixed, then cured at room temperature for about 10 days. The price of a 100-g packet is about $2.20. Quality standards are $> 1 \times 10^9$ rhizobia and $< 1 \times 10^6$ contaminants, although the latter target is often exceeded. The adhesive is gum arabic and included within the package as wettable powder.

5.5.4 Malawi

An inoculant is produced at pilot scale by the Chitedze Agricultural Centre. The product is labelled "Chitedze Inoculant" and is only intended for use with soyabean. It is packaged in 50 g packets sold for $0.60 each with about 15,000 produced over the past year. The carrier is sugarcane filter mud. Broth is produced in 5 L flasks, manually injected and hand kneaded. The final product is cured for 6 weeks, and then sold directly from Chitedze. Quality is assessed both in broth culture and by plate counts of cured inoculants. Its quality target is 1.0 x 10^9 rhizobia per g but contaminants are not considered.

5.5.5 Mozambique

No inoculants are produced in Mozambique, but an assortment of products have been imported. These inoculants include both liquid and solid formulations. Liquid formulations did not perform as well as solid ones and the best performing inoculant was BIOFIX from Kenya.

5.5.6 Nigeria

An inoculant manufacturing plant is under construction at IITA, Ibadan as part of the larger Business Incubation Platform. The purpose of the factory is not only to produce inoculants for sale, but also to demonstrate their economic viability to private sector investors and to provide incentives and training for their future operations. Production will begin in March 2014 under the brand name NoduMax sold in 100-g packets intended for soyabean. Production targets are 12 tons in the first year increasing thereafter to 30 tons per year.

5.5.7 Rwanda

The Rwanda Agricultural Bureau produces inoculant intended for bean and soyabean at its Rubona Station. Production of this pilot product started in 2011 using standard strains and a local isolate. Inoculant is sold in 80 g packets costing $0.80 intended for 7 kg of seed with about 44,500 units sold over the past year. Independent product testing indicates that it provides about 1.0×10^6 rhizobia per seed. The inoculant relies upon a local peat carrier. Broth is cultured in a 25 l fermenter, manually injected and cured at room temperature. Sugar is the recommended adhesive.

5.5.8 Zimbabwe

Legume inoculants are produced by the Soil Productivity Research Laboratory (SPRL) at Marondera. It produces nine inoculants for soyabean, common bean, groundnut, cowpea, crotalaria, lucerne (alfalfa), pea, calliandria and leucaena. The strains in use by the factory are USDA 110 (soyabean), CIAT899 (bean), MAR 1510 (cowpea, groundnut) and others. Sugar cane bagasse is milled, autoclaved and injected with dilute broth. The product is cured at 28°C for 14 days and contains at least 10^9 rhizobia and less than 10^6 contaminants per g. The product is sold in 100 g sachets for US $5 each. Production for the 2012-2013 growing season was 86,300 units, 93% of which were for soyabean. Sugar is the recommended adhesive.

Table 5.7: Summary of inoculant production, coverage and value in six N2Africa countries.

Country	Brand	Package g $unit^{-1}$	Quantity units yr^{-1}	Price \$ $unit^{-1}$	Seed rate kg $unit^{-1}$
DR Congo[a]	RhizoFix	50	experimental	2.2	5
Kenya	BIOFIX	10-150	220,000	\$22 kg^{-1}	12
Malawi	Chitedze	50	15,000	0.6	5
Nigeria[b]	NoduMax	100	120,000	2.5	12
Rwanda	RAB	80	44,500	0.8	7
Zimbabwe	Marondera	100	86,300	5	25
Total			485,800		

[a] Inoculants support field research only. [b] Projected from detailed plans by IITA Business Incubation Platform

A summary of inoculant production activities within the project is presented in Table 5.7. In terms of quantitative indicators, this production exceeded original production targets by 15%, respectively. The large difference in these achievements in increased production and coverage is primarily due to the emergence of smaller packaging of BIOFIX in Kenya, where more packages are applied to less area. Efforts to privatize production were not as successful as a large proportion of inoculant manufacture occurs among parastatals and research institutes.

It is important that strategic alliances be formalized between public and private sectors in order for inoculant production capacity in sub-Saharan Africa to improve and expand. The role of N2Africa and other international agencies with expertise in applied and developmental research is also important. A framework was developed that describes the relationships among the public sector, private business and international agents relating to rhizobial curation, strain evaluation, inoculant product formulation, manufacture, standards, use, regulation and trade.

5.5.9 **Rhizobial curation**

Most N2Africa participants have initiated or greatly expanded rhizobial culture collections but the degree of their institutionalization and maintenance beyond project lifetime is uncertain. Continuity in the supply of elite strains is an important role of international partners, and it is imperative that the project's unique and elite strains be assembled, more completely documented and entered into long-term storage with provision to supply them to future interested parties.

5.5.10 **Strain evaluation and recommendation**

Culture collections are routinely being tested, with new entries undergoing routine tests, and new tests being applied to better document the larger collection. These efforts should lead to strain recommendations for specific legumes, their varieties and even habitats that are then directed toward commercial interests. Inoculant producers will also test strains, but along different criteria aimed at product improvement.

5.5.11 **Inoculant formulation and manufacture**

Clearly it is for the private sector to lead in inoculant formulation and manufacture. Nonetheless, scientists working for public research organisations have an important role in providing advice and in ensuring quality control procedures are in place and effective.

5.5.12 **Inoculant use.**

While the formulation and manufacture of inoculants is led by the private sector, promotion and instruction on their use is shared between the private and public sectors. Commercial inoculant producers develop advertising campaigns around their products, and advance this information through input supply networks. But this approach is insufficient to reach poorer

Figure 5.7: Pictorial guidelines on inoculation using the slurry technique were developed by N2Africa for use in extension training.

and more remote households. N2Africa clearly demonstrated through its outreach activities and partnership arrangements that the project also has an important role to play in developing training materials (Figure 5.8) and extension campaigns.

5.5.13 Inoculant standards, regulation and trade

It is the role of governments to establish standards for the labelling and contents of legume inoculants, the private sector to develop processes and competencies to comply with those standards and for international agencies to compare and advise upon those standards. Regulation may be regarded as a separate but equally important issue, as this serves to assure compliance with standards and ultimately to protect customers from inferior products. This is an area in which N2Africa collaborates closely with the COMPRO project (http://www.compro2.org).

5.6 Policies affecting legume inoculants

In order to fulfil the promise that improved BNF technology holds for smallholder farmers, quality inoculants need to be readily available and accessible. Current trade barriers should be lifted in order to make this possible. The requirements for the registration of inoculant products are prohibitive in some countries and should be streamlined to allow inoculants produced or approved in one country to be used in another without undue regulatory hurdles. Import restrictions to protect national or nascent inoculant production industry will be counter-productive if sufficient quality inoculants are not available. Rather governments should focus on the quality control of the inoculants brought onto the market and putting a regulatory framework and control mechanisms in place. For the purpose of quality control, existing laboratory facilities are in place but often these need to be upgraded and sanctioned to handle routine quality control testing. Quality control should be conducted at different stages in the input supply chain and expiration dates set accordingly. Return policies for expired stock should be put in place that are legally binding for manufacturers and distributors in order to prevent inferior products being sold to farmers. Independent bodies should conduct quality control, but manufacturers should be encouraged to conduct quality control procedures in-house to guarantee the quality of their products (e.g. broth testing before mixing). Building a sustainable inoculant production industry should be based on the commercial production by private companies or through public-private partnerships, whereby governments offer both technical assistance and financial incentives while this industry is at its earliest stages of growth (Huising *et al.*, 2013).

5.7 Conclusion

Originally it was intended that Rhizobiology activities would be conducted at only three established laboratories: MIRCEN in Kenya, IITA in Nigeria, and SPRL in Zimbabwe. But this approach was overturned at the project inception meeting where it was decided that laboratories would operate in every country. This decision was based upon the more localized needs of bio-prospecting, field testing and inoculant quality assessment but also required that additional laboratories be commissioned or upgraded in DR Congo, Ghana, Malawi and Rwanda (Bala, 2011) and that the number of technicians and young scientists receiving training in Rhizobiology be increased (Koala *et al.*, 2011). This decision in effect slowed the pace of research early in the project as attention was diverted to building capacity of technicians and laboratories in many countries. In the end it resulted in more functional Rhizobium laboratories positioned to make substantial contributions in the future, particularly in bio-prospecting later in the project. Two of these locations went on to develop pilot inoculant production facilities (Woomer *et al.*, 2013).

N2Africa has played an important role in revitalized Rhizobiology in sub-Saharan Africa. This discipline was in decline with a decreasing number of soil microbiologists available to conduct research in this area. Seven countries now have functional laboratories and greenhouses, tested procedures are in use, technicians are trained and several MSc and PhD studies are ongoing or have been completed. In this way a cadre of expertise is now in place to support an emerging inoculant industry, government regulatory operations and further research. Our efforts have demonstrated the useful application of legume inoculants, particularly in soyabean and to a lesser extent in bean. Rhizobiologists are prepared to assist the private sector in commercializing inoculants and to assure that these inoculants meet international standards. In addition, bio-prospecting led to the characterization of 1437 cultures, the development of a culture database and the identification of 13 candidate elite strains.

6 Delivery and Dissemination of legume and inoculant technology

6.1 Dissemination approach and number of farmer households reached

The delivery of legume and inoculant technologies involves a number of activities. At the core is the dissemination of technologies through demonstrations on farmer's fields and the provision of technology packages to farmers to test on their own fields. For the demonstrations the best-improved varieties with high BNF potential, identified in agronomic trials and suitable for the prevailing agro-ecological conditions, were used. Demonstrations often consist of a control, a P-fertilizer application, and use of inoculants and combination of inoculants and P-fertilizer (the latter two in case of soyabean and in some cases common bean). The basic layout of the demonstration plot (for soyabean) is given in Figure 6.1, though variation in size of the plots occurs. Sometimes treatments include local versus improved varieties or the use of other types of inputs. Each demonstration uses best agronomic practice in terms of plant density and planting in line, and is supported by training in the use of inoculants and fertilizer. In the demonstration plots the farmer can observe the response to the use of the various inputs and decide which technology is best suited for him or her to use in their own fields (Figure 6.1).

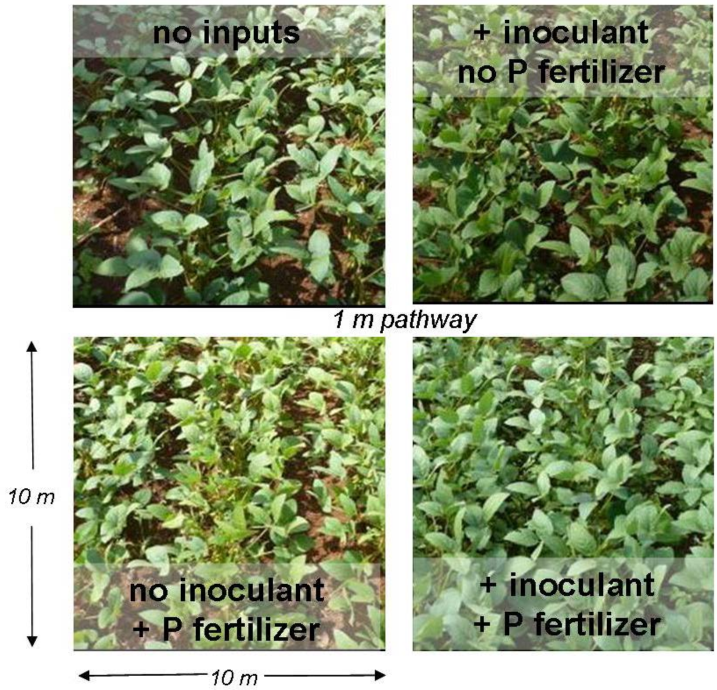


Figure 6.1: Basic layout of BNF technology demonstrations and typical results for soyabean planted with and without P-fertilizer and legume inoculant.

Apart from demonstrations, the project used field days, radio and TV broadcasting, and distribution of extension materials as dissemination tools (Table 6.1). Particularly field days in the rural settings have been a useful platform within Action Sites to showcase N2Africa legume technologies. At times media interactions resulted from these, yet particularly the autonomously initiated media events are noteworthy. For example, in DR Congo numerous radio broadcasts were made resulting from collaboration between N2Africa and 'Radio Maendeleo' based in Bukavu (Textbox 6.1), most widely followed in the region and with an estimated two million listeners.

Over four years, the N2Africa project has reached 253,299 farmers directly through its dissemination activities in the eight target countries (Figure 6.2). The target of at least 50% women participation was easily achieved in some countries, such as Rwanda, DRC, Kenya and Zimbabwe. In Mozambique, Ghana and Nigeria this criteria was not always met, due to a lower involvement of women in agriculture in general and on the working methods of development partners (see also Annex 7 on gender disaggregation of project beneficiaries).

Farmers qualify as having been reached if they have used at least two components of the N2Africa legume technology package on a minimum surface of 100 m^2. Such components could be the use of improved seed/new variety, legume fertilizer (P-based, gypsum, Sympal, etc.), use of inoculants on soyabean, better cultivation practices (including spacing, weed management, pest and disease management, post-harvest handling, etc.). All these farmers have had the opportunity to become

Table 6.1: Number of demonstrations, field days and media events in the eight N2Africa countries.

	Number of on-farm demonstrations[1]	Number of farmer field days[2]	Number of media events[3]
Ghana	1167	96	17
Nigeria	347	27	69
DR Congo	78	35	56
Rwanda	104	36	17
Kenya	355	82	21
Malawi	753	252	18
Mozambique	812	66	5
Zimbabwe	1257	39	5
Total	4873	633	208

[1] The number of demonstrations has been estimated from different sources. Where known, the number of Lead Farmers has been used, with cross-reference to M&E records on input distribution. Probably a conservative estimate as not all demonstrations of the satellite activities have been captured.
[2] The number of field days has been estimated from M&E records, country progress reports and milestone reports. Field days have generally been considered as 'extension events', but there have been quite a number of other (smaller) events that have not been reported systematically, explaining the higher number of field days for Malawi that reported on all field days.
[3] The number of media events is very difficult to ascertain. The number given here is most likely a very conservative estimate (see also the report 34 on milestone 4.4.4)

Textbox 6.1: Radio Maendeleo – Bukavu, DR Congo.

In 1993, several local development organisations created the non-profit community radio station: Radio Maendeleo – the first of its kind in South Kivu Province. Radio Maendeleo targets rural and urban listeners, informing and educating them on development issues in the region, the country and even abroad. At present, Radio Maendeleo is the most widely listened to station in the region; it can be received almost everywhere in North and South Kivu and even in Rwanda (Cyangungu) and in Burundi (Bujumbura and Cibitoke). It is estimated that more than two million people listen to Radio Maendeleo.

N2Africa staff has collaborated closely with Radio Maendeleo and produced numerous broadcasts on subjects related to legume production; ranging from general introduction to the N2Africa project, inoculation and soil fertility management to nutrition, processing, value addition and marketing issues. All broadcasts were done in Kiswahili, most were also done in French and some in Mashi, and all were repeated at different days and times.

During a significant period, the shows are done weekly. The broadcasts had an immediate feedback mechanism: people could call in with questions or send an SMS. Over time, thousands of requests for more information on the different aspects of the discussed technology have come in. In addition, in rural areas, people quite often organize 'radio clubs': they listen to the radio broadcasts together and may discuss the issues presented.

(See also: http://www.radiomaendeleo.net/)

acquainted with more productive legume cultivation and related aspects of marketing, processing, nutrition benefits, etc. and as such have been capacitated in improved legume cultivation for better health and income generation.

In addition to the 253,299 farmers reached directly through the project, at least some 31,000 farmers have been reached through satellite activities[1] (Huising, 2014). These satellite activities were conducted either by partners that were already involved in the project and have extended their activities to satellite sites, or by partners that were collaborating with N2Africa and for which the project provided technical information, training and inputs (inoculants, seed). We do not have exact information on the technology packages that were provided through these satellite activities.

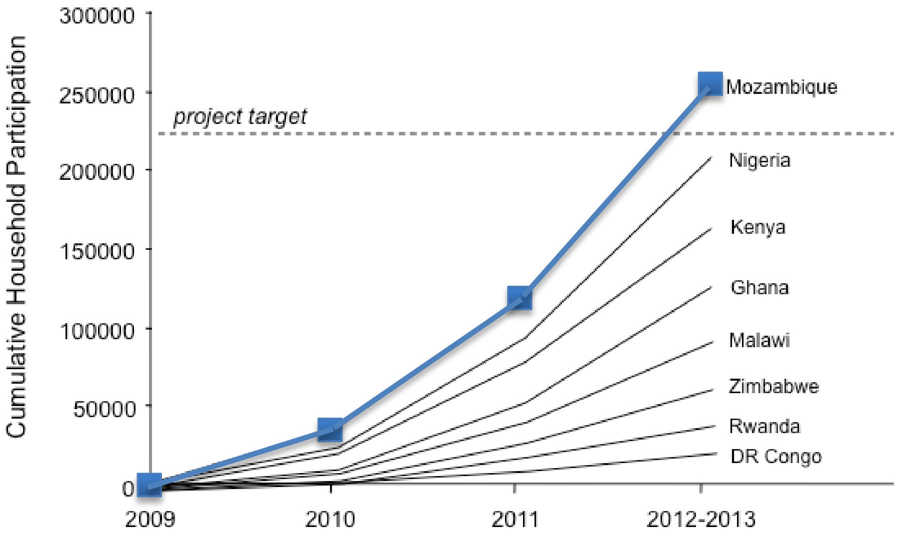


Figure 6.2: Number of farmers reached by the N2Africa project per country and totals over the years of project outreach.

Technologies have also spread beyond the direct beneficiaries through sharing of seed and information by N2Africa farmers with e.g. neighbours or relatives. A comparative study in Ghana, Kenya, Malawi and Zimbabwe showed that 60-100% of the interviewed farmers shared seed of soyabean, bean, cowpea and groundnut with others. Farmers shared seed with on average two to four, but sometimes even up to ten or eleven other farmers (the latter especially with soyabean in Malawi). These farmers in turn shared seeds with other farmers, up to a fourth 'generation'. The small sizes of the demonstration packages were sometimes mentioned as reasons for not sharing seed. Information about rhizobium inoculants and P-fertilizer was regularly shared as well, although the use of these technologies by 'indirect' beneficiaries was very limited; often because these inputs were not available on the market or were judged too expensive.

6.2 Strategic partnerships for the dissemination of legume and BNF technology

N2Africa has partnered with 32 outreach partners (see Annex 1) to achieve its dissemination objectives. These partners used their own staff to implement activities in the field, or made use of the national extension service or local community based or non-governmental and/or faith based organisations, farmer associations or groups to conduct the activities in the field. We refer to the latter as co-operators and these are not included in the total count of 32 outreach partners.

At the start, the project sought to establish contractual arrangements with partners to implement dissemination activities. The project proposed which technologies should be disseminated, provided the funding and facilitated the process by providing training (the 'training of trainers') and conducting planning meetings. The project had a Farm Liaison Officer (FLO) whose main task was to liaise with the partner organisations.

[1] This is a partial count, because we do not have the information from all satellite partners concerned.

To achieve success, it is important to make use of organisations that are well embedded within the local communities and have a wider reach at the same time. With the institutional setting differing from country to country, the role of the project also changes. In some countries the Project operated through some larger NGOs and make use of their local networks for the implementation of dissemination activities, whereas in other countries the Project worked more directly with local outreach partners and in particular instances N2Africa was directly involved in dissemination activities. So depending on how extension services are structured and the strength of the various actors/organisations operating in this field, N2Africa adopted a somewhat different organisational structure and mode of operation in each of the countries.

The above partnership model was effective in reaching large numbers of farmer households at the earlier stages of the project, but from a strategic, longer term perspective the above model is less suitable. Especially the nationally or locally operating NGOs depend on projects like N2Africa for their funding. From a survey amongst partners, it appears N2Africa provided a relatively small contribution in financial terms to the partner organisation (almost all indicate less than 25% of their total budget). This relationship model provides limited perspective for continuation of activities after the project has ended, which is likewise a concern to the Project. Though many partners have indicated their wish to continue in the project and with the dissemination of legume and BNF technology, a number of them dropped out. This suggests that N2Africa should engage more with (and target) farmer organisations, community based organisations and others, for whom legume enterprise may provide for viable business opportunity, through value adding activities or services provided, with a focus on enterprise and business development.

This model seems to have worked quite well in western Kenya, where farmer organisations are relatively well developed. The farmer organisation provides support to the progressing farmer (a farmer that progresses from being direct beneficiary of the project to producing legume crops on a semi-commercial basis). This support can be in the form of distribution of inputs, establishing a revolving fund that gives farmers access to inputs, establishing marketing collection points, or venturing into more specialized activities like seed multiplication. This model serves well for scaling

Figure 6.3: Cash box of the 'savings and loans committee' and harvest from legume enterprise (one feeds into the other) from a farmer community in Kasungu, Malawi (left); A collection point for soyabean in western Kenya facilitated by the N2Africa project (right).

out of activities, as these services are open to all members of the organization and provides a stimulus for farmers who have not been direct beneficiaries of the project to venture into legume production. In Kenya we have seen farmer organisations transforming themselves during the course of the project to provide this kind of services independently to their members and this gives a perspective for a more sustainable impact of the project (Figure 6.3). Malawi opens interesting perspectives in where legume enterprise promoted by N2Africa is linked to the ‘savings and loans committee’ providing for some financial security (Figure 6.3).

Establishing strategic partnerships with satellite partners is different. Satellite partners are often internationally operating NGOs that run projects for which they have their own independent funding. They turn to N2Africa because they consider the legume and BNF technology promising, but lack the technical capacity and information to organize and conduct dissemination campaigns and they may have a different focus and dissemination approach than the N2Africa project. An example is the ADVANCE project in Ghana that focuses on value chain development, in which soyabean is one of the value chains they address. They collaborated with N2Africa in setting up demonstration plots but used a ‘nucleus farmer model’ rather than the lead farmer model for the dissemination of the legume and BNF technologies (see also Textbox 6.2 below). Another example is TechnoServe in Mozambique, who target emergent soyabean farmers. For this purpose they use large demonstration plots measuring 0.5 ha in total, for which they cover all the costs associated with land preparation, inputs etc. N2Africa provides technical advice and training where needed. These satellite partners have the capacity to reach a large number of farmers through their own networks and these organisations, by adopting legume and BNF technology as important component of their development agenda, provide an important mechanism for generating sustainable impact of the N2Africa project.

In practice the distinction between outreach partners and satellite partners is unclear. The goal is to collaborate with sufficient organisations that are willing to adopt and able to promote BNF technology amongst the smallholder farmer. An interest in the technology is created by widely demonstrating its success and subsequently providing the technical assistance pushes the technology. The project has been successful in promoting legume and BNF technology amongst the development partners.

6.3 Legume technology packages adapted to the need of farmers’ groups, agro-dealers and development partners

N2Africa legume technology ‘packages’ included a set of inputs for a given legume (seed, fertilizer, inoculants, adhesive, etc.) plus recommended management practices (plant spacing, intercrop arrangements, etc.) combined in various different ways towards the goal of increasing BNF. The packages were accompanied by extension guidelines to explain application of treatments as well as other recommended management practices. These packages and extension messages were adapted from one season to the next as a result of advancing understanding of legume cultivation in the impact zones resulting from research and learning within dissemination activities. Which varieties were recommended depended on marketability (e.g. soyabean varieties with low oil content being preferred for food processing), or susceptibility to pest and diseases. Pest and disease management came to the fore as an important management consideration and was included in the extension messages. Other management considerations addressed during later stages of the project and included in demonstrations were intercropping systems, like maize - legume systems (e.g. Kenya), cassava – legume systems (e.g. DRC) and (dwarf) sorghum – legume intercropping systems, and staking systems for climbing beans. Table 6.3 provides some basic information on the various technology packages disseminated by the project in each of the countries. The type and amounts of inputs as well

Table 6.2: Technology packages disseminated in the N2Africa countries.

Country	Technology Packages	Varieties	Remarks
Rwanda	Soyabean-maize rotation	Peka 6 and SB24 (soyabean) ZM607 (maize)	
	Bush bean–cassava intercrop	RWR1668 and RWR 2245 (bush beans)	
	Climbing bean-maize rotation	Gasilida (climbing bean) Variety Pool A (maize)	
DRC	Soyabean-maize intercrop	SB24 and PK6 (soyabean)	
	Soyabean-cassava intercrop	SB24 and PK6 (soyabean)	
	Bush bean-maize intercrop	CODMLB001 and AFR708 (bush bean)	
	Bush bean-cassava intercrop	CODMLB001 and AFR708 (bush bean)	
Kenya	Soyabean	SB19 and SeedCo cv. Squire*	Demonstration of Sympal fertilizer blend
	Bush bean	Kenya Umoja	
	Climbing bean	Kenya Tamu and RVW 51348	Bamboo poles, string trellis used for staking
Malawi	Soyabean	Makwacha and Nasoko	Demonstration of Sympal fertilizer blend
	Groundnut	Nsinjiro and Chalimbana	Two planting dates, separated by two weeks
	Bush bean	Napilira and Kholophete	
	Cowpea	Sudan 1 and IT81E-16	Planting of *Tephrosia vogelii* and instruction for using this to prepare bio- insecticide
Mozambique	Soyabean		Experiment with different planting dates (two and four weeks apart) Different plant spacing applied; Mechanized vs. manual tilling
	Groundnut	Various	Testing on drought resistance, tolerance to rosette virus and for size of nuts; effect of planting date and use of lime and P fertilizer
Zimbabwe	Bush bean	Cardinal, Speckled Ice and Pan 159	Demonstrating effect of using inoculants
	Groudnut	Natal Common	With or without gypsum and lime
	Soyabean		With basal lime application
	Cowpea	CBC1 and CBC2	Lime applied to all plots
Ghana	Soyabean	Jenguma	Demonstrating use of pre-emergence herbicide and insecticide
	Cowpea	Songotura, Apaagbala and IT90K-2777-2	Demonstrating use of pre-emergence herbicide and insecticide
	Groundnut	Chinese, Samnut 22 and Samnut 23	Demonstrating effect of using KCL fertilizer
Nigeria	Soyabean	TGX 1955-3F plus traditional variety	
	Cowpea	IT99K-205-8 plus traditional variety	
	Groundnut	RMP 91 and one traditional variety	
	Groundnut- cereal (maize or sorghum) intercrop	Comparing improved and traditional groundnut varieties	Demonstrating effect of various arrangements
	Cowpea-cereal (maize, millet or sorghum) strip or relay cropping		Planting of cowpea when maize is at silking stage and planting two weeks after planting of cereal

* Maize-soyabean intercropping system was added to the demonstrations in later years; different varieties were used for the long and short rainy seasons

as the management options may differ between and even within the countries (Table 6.2). Also type and amounts of inputs may change from one season to the other and finally the technology kits differ when intended for demonstration plots and when intended for use on farmers' own fields. The actual number of technology packages is there for higher than the 28 listed in Table 6.2. For more information see Section 4 and N2Africa Report No. 035. Data collected from various demonstrations is available on the project website.

An inventory among FLOs and dissemination partners gave insight in the way farmers themselves adapted the demonstrated technologies in the year after they participated in the project. This inventory (in DR Congo Ghana, Kenya, Malawi, Rwanda and Zimbabwe) showed that farmers often changed technologies from mono-cropping of legumes in the N2Africa demonstrations to intercropping of legumes with cereals, and by increasing plant densities compared to plant densities used in the demonstrations (e.g. by allowing several plants per planting station). Adaptations were often applied to reduce the workload and to maximize the use of limited land, or as risk mitigation strategy (in one crop fails you would still harvest from the other), but sometimes came at the cost of reduced yields. Farmers proved ingenious in developing alternative staking methods for climbing beans using live trees, strings and intercrops as alternative staking methods.

Training and extension accompanied the dissemination of the above-mentioned technology packages, whereby the materials were often written in the local language (Kiswahili, Kinyarwanda, Chichewa, Mashi and Shona). These training and extension materials cover various aspects of legume production, from best agronomic practices to pest and disease management and to 'how to inoculate', but also include various materials on legume processing. The materials developed by the project aim at diverse target groups such as farmers, women, extension workers and agro-dealers. Annex 2 provides an overview of the training and extension materials produced and used in the different countries. The training materials are also available on the N2Africaweb site (www.n2africa.org).

6.4 The Lead Farmer approach

In order to disseminate legume technology packages to the many thousands of farmers the project and its partners adopted the Lead Farmer approach, mentioned earlier. In this approach, each Lead Farmer works with a group of 15 to 30 farmers, located in his/her vicinity. The Lead Farmer is the main contact for the project and partner organisation; she/he is capacitated through training on legume cultivation and the Lead Farmer is to share the newly gained knowledge with his/her group members. The demonstration plot is established on the Lead Farmer's land, and in additions sometimes also on the land of a satellite farmer.

A case study done in Zimbabwe proved the Lead Farmer approach to be effective in dissemination of knowledge to a large number of farmers. Most of the group members around Lead Farmers showed an increased level of knowledge on BNF technology. The practical and theoretical knowledge on inoculation and biological nitrogen fixation were ranked by farmers as the most important subjects taught. The survey also showed that the most effective Lead Farmers were the ones selected by their peer farmers rather than being chosen by partner organisations and/or agricultural extension officers. In turn, farmers with relatively larger size of the landholding seem to participate more effectively and learn more. Farmers with smaller land sizes were nevertheless better represented in the N2Africa project, since they said they needed to keep improving their soil fertility.

The lead farmer would ideally unite in him or herself characteristic of a model farmer, an extension worker, a community worker, and development worker or service provider (e.g. for bulking, gaining access to loan facilities and linking farmers to markets). In N2Africa we did not select the lead farmer purposefully, but rather these presented themselves as those who had already been involved with the outreach partner or co-operator in previous projects. From the various interviews, of which several on camera (see Annex 4), it seems that the Lead Farmer is mainly motivated by wanting to play a meaningful role in and for the community, and already has a leading role within the community (see also Textbox 6.2). The lead farmer brings his or her existing network to the project, with the question, though, whether that network represents the (type of) farmers the project wants to reach. Furthermore, some of the functions of the lead farmer could be (or might be) better performed by the farmer group or organisation, and the relation of the lead farmer to and within the farmer group or farmer association should be considered. Certainly, the lead farmer has played an important role in organising farmers, especially where farmer organisations are weak and the project has left a legacy where these structures survive the project. The lead farmer approach has obvious advantages and it would be useful to investigate how to make better use of the Lead Farmer as mechanism in dissemination of legume and BNF technology and improve its effectiveness in bringing about changes in knowledge levels, farming practices and adoption of technologies. In the second phase of N2Africa we could improve on the monitoring and evaluation of the Lead Farmer approach and improving feedback to the Lead Farmers to strengthen their role in disseminating the technology should be given more attention.

Textbox 6.2: George Mkwamba – N2Africa lead farmer in Malawi.

In Malawi, George Mkwamba is a successful Lead Farmer. George was approached by nine farmer groups looking for an extensionist after the previous government extension agent resigned. George started coordinating extension activities in 10 farmer groups comprising 200 households. His case suggests that a higher education level, previous exposure to trainings and related work and higher socioeconomic status are some of the attributes of an effective Lead Farmer. Findings of this portrait and a more general study on lead farmers in the project have helped devising selection criteria of good Lead Farmers to support organisations advocating Lead Farmer approaches. Due to the shortage of extension staff in many countries, governments may also want to make use of successful Lead Farmers to support their activities, as in the case of George Mkwamba.

George Mkwamba (in blue shirt) conducting a Field Demonstration

6.5 Seed multiplication to support dissemination campaigns, and for sustained impact

From the start of the project it was recognized that the availability of seed of good quality, the right varieties and in sufficient quantity is a challenge that needs to be addressed by N2Africa. The Project relied on various sources, including seed companies and research institutes, to acquire seed for its dissemination campaigns. The proposed engagement with the seed industry to procure enough seed of the preferred varieties has not been effective, leading to seed being disseminated in small amounts, to the dissatisfaction of farmers, and in some cases to late planting. Problems were also encountered with respect to the quality of seed (mixed varieties, poor germination rate). Securing enough seed and distribution of this seed for later seasons with the rapid expanding numbers of direct beneficiaries of the project was a major challenge.

Instead, a system of seed repayment and community-based seed production has been established. All farmers who received seed of improved varieties through the project have been encouraged to repay 2 kg of seed for every kg of seed received back to the project for redistribution to other farmers. While

Figure 6.4: A soyabean seed multiplication field set up by a community and women based organisation (ICODEI) in Birava, DRC. Producing quality seed is still a challenge.

this was challenging during the first period of the project, great improvements were made after the first seasons in all countries, which assisted a lot in availability and spread of seed. Success of this payback system also depended on the type of crop. For example, in Kenya this was more difficult to organize for climbing beans where the collection and aggregation of the grain was not centrally organized. Nevertheless, our impression from evidence in the field (e.g. Figure 6.4) is that at least half of the farmer communities have become self-sufficient in their seed requirement to the end of the project (data not available).

Community-based seed production requires availability of appropriate inputs, technical backstopping and close supervision from experts. If these requirements are met, community-based seed production can be a vital element in sustainable supply of seed and in the long run even an income generating activity for farming communities. For example, in the 2011-12 season in Zimbabwe, the seed generated through community-based seed production was often of higher quality than commercially purchased and certified seed.

Table 6.3 gives an idea of the amount of seed distributed in the project. By month 18 of the project (April 2011) the amounts were still modest (Turner, 2011), but towards the end of the project, and depending on the number of farmers reached, the amount of seed distributed ranged from 15 t to 25 t or more per season per country. This includes community-based seed multiplication. Mozambique represents a particular case in that a number of satellite activities required large amounts of seeds because of the extensive dissemination campaigns using large demonstration plots, explaining the major part of the 288 t of legume seed distributed in the 2012/13 season (see Huising, 2014). It was possible to distribute such amounts of seed in Mozambique as IITA is heavily involved in seed multiplication funded by various other projects.

Securing the quality seed required and organizing the distribution of seed and other inputs in a timely manner is critical towards achieving success in the project. Late planting reported on several occasions by various countries carries a penalty on the yield and therefore influences the adoption of the technology. This critical aspect should be given more consideration in future.

Table 6.3: Indication of the amount of seed distributed to farmers for dissemination purposes in the various countries at varying points of time in the project.

Country	Amount of legume seed distributed by month 18 (t)	Additional information on amount of seed distributed at later stages (t)
Kenya	14.18	223 t soyabean seed and 1.40 t climbing beans distributed by year 4
Rwanda	1.98	4.78 legume seed up to and including the 2011/12 short rains season (plus 189,000 cassava cuttings and 714 kg of maize seed)
DRC	1.30	7 tons of common bean and soyabean in total
Zimbabwe	3.35	24.13 t legume seed deployed (for 2011/12 and 2012/13 seasons)
Malawi	3.43	14.4 t of soyabean seed, 7.8 t of groundnut seed and 7.0 t of bush bean seed distributed in total during the lifetime of the project.
Mozambique	2.04	393 t of legume seed, mostly soyabean, distributed over 4 years
Ghana	11.56	57 tons of improved legume seed distributed over four years
Nigeria	16.46	34.0 t legume seed distributed during the 2010, 2011 and 2012 seasons

6.6 Inoculant distribution and sustainable supply

Availability of inoculants is of crucial importance to enhance soyabean production in smallholder farming systems and this continues to be a challenge in several of the N2Africa countries. Kenya and Zimbabwe have in-country production capacity, with the supply through agro-dealers being more reliable in Kenya than in Zimbabwe. While promising developments are taking place in some countries, inoculant availability may remain a challenge for smallholder farmers.

N2Africa has engaged with agro-dealers in different ways. Of importance has been the training of agro-dealers that has taken place in all but two countries. In total 249 agro-dealers have been trained (see also section 7 on capacity building "working with agro-dealers"). In making inoculant distribution work, each country requires a specific approach. In Kenya, MEA has advanced well in establishing distribution of inoculants through agro-dealers. SPRL in Zimbabwe has progressed somewhat in planning for improved distribution of inoculants into communal areas, but implementation of these plans lags behind. In countries where no inoculant production takes place, N2Africa had to import inoculants. In these countries, distribution networks are generally lacking and agro-dealers are generally less knowledgeable on inoculants. In addition, N2Africa has assisted other organisations to have access to inoculants (see for example the case of ADVANCE, northern Ghana). Because of problems with procuring and distributing inoculants, inoculants arrived too late and planting was subsequently also delayed. The logistics of input distribution require more attention.

The project has been able to import inoculants on a research permit only. There are obstacles in many countries for the registration of inoculant products and obtaining import permits. N2Africa Report 63 (Huising *et al.*, 2014) gives recommendations for the regulation of inoculant products and improving cross border trade. In the meantime advancements have been made in increasing within-country production and quality of the inoculants. Towards the end of Phase I efforts have been undertaken to involve and facilitate agrodealer associations and distributors in the supply of inoculants.

6.7 **Linking farmers to markets**

Linking farmers to markets is essential for the long-term success and adoption of improved legume technologies by smallholder farmers. Much of N2Africa's work towards developing legume market linkages for participating farming communities has built upon existing initiatives. Working with satellite partners, NGOs and companies already involved in linking small-scale farmers to formal markets builds upon the strengths of both partners. N2Africa offers improved technologies which can generate better quality legumes in larger volumes, and NGOs and companies provide the market requirements (quality and quantity specifications, packaging, price information). In some cases companies assist with provision of inputs on credit. In other cases, NGOs and other projects have contributed in building capacity of farmers in marketing. As a result, a variety of different approaches have been used.

In Ghana 1000farmers were linked to the ESOKO marketing platform (see Textbox 6.3). Collection points were established in Kenya, DRC and Rwanda. In Kenya 16 collection points were established in collaboration with Promasidor through which 604 tons of soyabeans were traded during the last two rounds of announced buying (see also Textbox 6.4). Also, three processing plants were launched in the region in 2013 that consume a total of 30 t of soyabean per year and that are exclusively supplied by N2Africa farmers. In DRC nine collection centres were established at which farmers store their soyabean and beans, to be sold at a premium price three months after harvest. In Malawi

Textbox 6.3: Agricultural Development and Value Chain Enhancement (ADVANCE).

The Agricultural Development and Value Chain Enhancement (ADVANCE) program partnered with N2Africa in 2011. The ADVANCE program builds the capacity of value chain actors along the supply chains of agricultural crops such as rice, maize and soyabeans. In this value chain approach smallholder farmers are linked to markets, finance, inputs, equipment services and information through relatively larger nucleus (commercial) farmers and large traders who have the capacity to invest in these chains. N2Africa provided Training-of-Trainers and technical backstopping and facilitated the import of inoculants for ADVANCE project participants – agro-dealers and farmers. ADVANCE's promotion of soyabean inoculants has resulted in increased awareness among agro-input dealers and commercial farmers in the importance and use of inoculants and two agro-input companies are now willing to import inoculants into Ghana for sale in Northern Ghana.

Textbox 6.4: The Progressing Farmer approach in Kenya.

A dynamic, stepwise process of farmer recruitment, initial BNF technology testing and subsequent incentivizing farmers led to widespread adoption of BNF technologies in Kenya. The project recruited farmer associations, grassroots organizations and local NGOs to participate in its activities, providing farmer training, establishing roadside BNF technology demonstrations each season and distributing small, one-time BNF technology test kits to interested households. By the end of the project it worked with 27 such groups, trained 226 Master Farmers, conducted 355 technology demonstrations and worked directly with 37,464 households. Distribution of small BNF technology packages, intended for 200 m^2 to these households only once, established that inoculation with BIOFIX inoculant, in conjunction with basal fertilization without nitrogen, was effective in terms of both nodulation and yield increase. Farmers receiving seeds of improved legumes from the project repaid them to their respective organizations at a rate of 2:1, allowing for exponential growth in seed availability and farmer participation. "Progressing Farmers" were then provided opportunity to expand their grain legume enterprise. In return for bagging 12 kg seed and clearing 1/2 acre (2000 m^2) of land, they received Sympal fertilizer and BIOFIX inoculant worth about $8.60 on credit. This loan was later repaid in soyabeans (15 kg) at one of 16 local collection points where they marketed their crop. Later, each group was aligned with one or two local agrodealers that received training in handling and marketing BNF technologies. This approach permitted several farmer groups to initiate revolving funds to purchase Sympal fertilizer and BIOFIX inoculants in bulk on behalf of their members and to encourage local agrodealers to stock them as well. By project's end, all seeds were being produced by farmers themselves, and over 56% of fertilizer and inoculants were purchased on credit, with the remainder extended to first-time farmers as BNF technology tests, many of whom become next-season Progressing Farmers.

representatives from the various farmer groups have been introduced to the commodities exchange systems (the AHL Commodities exchanges – AHCX – and the Agricultural Commodities Exchange of Malawi – ACE) as a possible venue through which to sell their soyabean and beans. In Zimbabwe the grain is sold to the grain marketing board, or is being produced in out-grower schemes with specific companies and farmers are trained to take the lead in linking to markets and negotiate and sell directly to processing industry. Figure 6.5 shows groundnut grain collected at central point in Mudzi district, awaiting transport to the processing industry.

6.8 **Improved nutrition and legume processing**

Improving nutrition through increased consumption of legumes at household level and value-added processing to generate income opportunities for women has been an important aspect in the promotion of legume crops and the subsequent uptake of their cultivation by small-scale farmers. Soyabean in particular might not be widely known and therefore increasing people's knowledge on its use and nutritional value is essential to increase local demand.

Women tend to dominate activities related to local processing and use of grain legumes, and project interventions concerned with training on nutrition as well as processing of all legume crops have consequently been tailored to reach women farmers and rural women's groups in particular.

Across the eight N2Africa countries, the activities focussed on processing and improving nutrition from legumes at household level and beyond have been numerous and very diverse. Activities included education on the nutritional benefits of legumes, training on processing of soyabean for soya milk, yoghurt, blended flour etc. and demonstration of various recipes for snacks, beverages and meals, promotion of foodstuffs on fairs, cooking contests and in cases capacitating in business skills to facilitate income-generating activities.

We have not systematically monitored the outcome and impact of these activities, but there are several examples illustrating the relevance and effect of such training. For Kenya, it is estimated that towards the end of the project 20% of the total soyabean produced is consumed at home, with an additional 20% is used locally for value added processing and sold on local markets and 60% is bulked and finds its way to the market for processing. From the early impact assessment in Kenya it shows that 84% of the households consumes soyabean, and 31% of the households routinely processes soyabean, mostly for snacks and to lesser extent for mixed flour and making beverages, where this was practically zero at the start of the project. Twenty seven per cent of the households has used or is using soyabean for making soya milk.

In Rwanda a group of women representing different Action Sites were trained in soyabean processing (training of trainers) to extend the training to women in their communities at their own volition and using their own means. There are several reports of women having started their own business, varying from one women preparing tofu for wedding ceremonies, to supplying milk and foodstuffs to orphanages or supplying snacks to local restaurants. Also in Nigeria women report to make snacks that they sell at schools or from their home (Figure 6.5). In Kenya, 9 out of the 26 co-operators are involved in legume processing initiatives, with some of the products being sold from local shops.

Figure 6.5: Various soyabean, cowpea and groundnut derived products demonstrated by a women group from northern Nigeria (Kano).

A nutritional study in northern Ghana showed that children (between 2 and 5 years old) of N2Africa participants had a more nutrient adequate diet compared with non-N2Africa participants and consume more legumes, nuts and seeds, but there was no difference in nutritional status. Particularly women who had participated in N2Africa activities and people who had received training on soyabean preparation for home consumption used the legumes yielded from the farms for home consumption.

See also Annex 3 for an overview of materials on post-harvest management, processing, value addition, etc. as part of the training and extension materials produced and distributed by N2Africa. It has become clear that recipes are quite specific to countries and even regions within countries but a lot of work has already been done in collecting and collating recipes. In most countries, N2Africa has built on existing materials and initiatives – also in recognition limited staff capacity on nutrition, processing and value addition of the N2Africa project itself.

In conclusion, the dissemination of N2Africa legume technologies has been successful. Legumes offer a wide diversity of options that are appropriate for the various agro-ecological conditions and for different farmers. They fulfil needs in terms of nutrition, income generation, increased soil fertility and has positive effects on overall farming system performance. The success is attributed to the differentiated approach N2Africa has adopted for the various countries, extensive involvement and close collaboration with outreach partners and effective linkages to other initiatives and projects.

7 Capacity Development in BNF Technologies

Capacity building across a wide range of skills occupies an important role in the project, particularly in applied research and technology advancement and application. These activities include; technician training in Rhizobiology; graduate-level academic training, training of extension supervisors and farm liaison specialists, grassroots training in BNF technologies and public access to N2Africa publications and outcomes. The Capacity Building, though an objective on its own, aimed to address the needs of the project for trained and skilled staff to carry out its research and dissemination activities. Also the degree training was aimed to contribute directly to the outcomes of the project. The team necessarily worked closely with scientists across the project to provide the training and develop training materials. We were deeply saddened by the untimely death of Mr. P.O. Ngokho, a dynamic young Training Officer, midway through the Project.

7.1 Technical Training in Rhizobiology

The project provided short-term training in Rhizobiology to national technical staff in two stages. At the project onset, three sub-regional training courses were organized to introduce project partners to our standardized methods to culture and characterize rhizobia and particularly in strain effectiveness testing (Koala *et al.*, 2010). Following this basic training, demand-driven short courses were organized to backstop project activities related to inoculant production and quality assessment. In both cases, the Rhizobiology Team designed and presented course materials with logistical support from the Capacity Building staff.

7.1.1 Technician Training in Rhizobiology

The purpose of this training was to strengthen skills in basic microbiology as related to strain isolation and characterization, inoculation technique and inoculant production and quality control (Koala *et al.*, 2011). This course was open to technicians in need of mid-career training and to incoming graduate students working with the project (Figure 7.1). Each participant was provided with a full set of training materials used in hands-on laboratory and greenhouse exercises. The workshop concluded with discussion of expected follow-up activities and development of a country action plan. Originally only 12 staff from three sub-regional laboratories were to be trained at a single venue; instead we concentrated on the existing national laboratories and training was offered to 29 technicians and graduate students (38% women) from all eight countries (Koala *et al.*, 2011).

Figure 7.1: Technicians examining root nodule interiors at the MIRCEN training course.

The first of three training workshops was conducted in September 2010 in Kenya, at the Nairobi MIRCEN and the BIOFIX inoculant factory in Kenya. Twelve participants (50% women) from the Democratic Republic of Congo, Kenya and Rwanda attended the course. The schedule and training manual developed for this two-week course was modified for use by the following two courses (Woomer *et al.*, 2011). The next training course was held at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, in November 2010. Six participants (40% women) from Ghana (2) and Nigeria (4) attended the training. The final training course was conducted at the Soil Productivity Research Laboratory (SPRL), Marondera, Zimbabwe in September 2011. There were 11 participants (27% women) drawn from Malawi (3), Mozambique (2) and Zimbabwe (6).

Clearly, the initial training of technicians and incoming graduate students was important to the later successes in rhizobiology. Because laboratories at national level were targeted, among them the less advanced (Bala *et al.*, 2011), the training was more basic than originally intended. Nonetheless, trainees concluded the course with both, important new skills and an understanding of their critical role within the larger project. Furthermore, these trainees returned to their respective laboratories to assist in their upgrading. These training events provided the first opportunity to test some of the early rhizobiology protocols; some problems were uncovered and the protocols amended. In some countries the upgrading of the laboratories and training of staff fell behind schedule (DR Congo, Malawi, Mozambique).

7.1.2 **Thematic short courses**

After the initial technical training in its first year, the Project intended to conduct annual, sub-regional short courses on specialized topics as needed, training at least 90 key technical staff from the 3 impact zones. N2Africa fell well short of this goal, conducting only two such courses on Legume Inoculant Technology and Quality Control Procedures. The first such course was held at the Nairobi MIRCEN from 4 to 22 July, 2012 and another at IITA from 8-17 July 2013, both facilitated by Dr Anabel Vivas-Marfisi.

Figure 7.2: The Inoculant Production and Quality Control Workshop was organized by the NAIROBI MIRCEN, facilitated by Dr Anabel Vivas-Marfisi and included 12 participants from eight countries.

The training focused upon the latest approaches to manufacturing legume inoculants and providing quality assurance. Thirteen specialists (45% women) from Ethiopia, Kenya, Malawi, Nigeria, Zambia and Zimbabwe participated (Figure 7.2). Its structure was very practical, dealing with the maintenance of mother and working cultures, recognizing contaminants, batch fermentation and its injection and performing quality control tests. Also included were the use of serology and PCR analysis in strain and species identification, as well as a visit to the BIOFIX factory. Issues under consideration at the factory included batch-level purity checks, adjusted approaches to carrier sterilization and improved curing.

A second workshop was conducted at IITA-Ibadan, and co-sponsored by Murdoch University (Australia), during 8-17 July, 2013 (Vivas-Marfisi, 2013). The workshop offered practical experience in batch fermentation cultures, inoculant injection and performance of quality control tests to 11 attendees from Ghana and Nigeria. Participants also visited the Nodumax inoculant factory under construction to provide them with a general overview of the design of a medium-scale legume inoculant manufacturing facility. The training manual is available on http://www.n2africa.org.

The reasons for the less-than-targeted additional short courses is found in the three basic training courses held, instead of the one planned originally and budgeted for; and as a result 17 additional persons were trained. The subsequent Nairobi and IITA short courses trained 23 more, bringing the additional trainees to 39, or 43% of the targeted 90. Perhaps the target of 90 trainees over three years was set too high, considering that only eight relatively small rhizobium labs participated in N2Africa activities. Nonetheless, we consider the overall goal of more and better-trained laboratory technicians positioned to produce greater amounts of higher quality legume inoculants to be achieved.

7.2 Advanced Degree Training

The N2Africa project supported graduate level academic training focused upon key knowledge gaps in Legume Agronomy, Rhizobiology and Technology Dissemination. Plans were drawn for 14 MSc and six PhD candidates to be identified through competitive calls and divided among the three sub-regions equally. Half of these candidates were to be women. The MSc students studied in African Universities while PhD candidates attended overseas universities (Giller and Koala, 2010). The larger goal is to establish an elite young cadre of African scientists with expertise in BNF technologies able to pursue practical research goals, but at the same time their topics directly addressed project research tasks. In Rhizobiology, for example, all rhizobial collection and testing was conducted by graduate students.

Table 7.1: Advanced degree training by sponsored N2Africa students, their research topics and universities.

Country	Students		Research Topics			University
	MSc	*PhD*	Agronomy	Rhizobiology	Dissemination	*(PhD in italics)*
DR Congo	3	*0*	2	1		University of Nairobi, Kenyatta Univeristy
Ghana	2	*1*	1	2	-	Kwame Nkrumah University of Science and Technology, *Wageningen University*
Kenya	3	*1*	1	3	-	University of Nairobi, Moi University, Egerton University, *Murdoch University*
Malawi	2			2	-	Bunda College, *Murdoch University*
Mozambique	2	*1*	2	1	-	Bunda College, Catholic University of Moçambique, *State University of Londrina*
Nigeria	2	*1*		3		Bayero University Kano, Ahmadu Bello University, *Murdoch University*
Rwanda	2	*1*		2	1	Catholic Institute of Kabgayi, University of Nairobi, *Wageningen University*
Zimbabwe	2	*1*		2	1	University of Zimbabwe, *Murdoch University*

7.3 MSc Scholarships

The program supported 17 MSc candidates attending 13 African universities (Table 7.1 and Annex 5). Women comprised 47% of those receiving MSc scholarship awards. Their research topics addressed Rhizobiology (47%), Legume Agronomy (41%) and Technology Dissemination (12%). The sponsored MSc students exceeded the original target by 21%, mainly because DR Congo did not identify a PhD candidate and the opportunity was replaced by two MSc students trained in Kenya and two late awards were given to Mozambique. Only one student discontinued his studies. Twelve of the MSc candidates graduated in 2013 and the remainder is scheduled for 2014.

7.4 **PhD Scholarships**

Almost all PhD scholarships were directed toward Rhizobiology because of a paucity of young, top-level African professionals in this discipline. Six scholarships were awarded to candidates from six countries, but only one woman was among them (Table 7.2). All of them are currently studying overseas at Londrina University (Brazil), Murdoch University (Australia) and Wageningen University (Netherlands), but their field research is conducted in their home countries. In general, admission was delayed due to issues with admissions and immigration requirements, and all students are not expected to graduate until 2015 and 2016.

Table 7.2: PhD scholarships within N2Africa

Aliyu Abdullahi Anchau is a Nigerian studying at Murdoch University. His research examines the genetic diversity of rhizobia associated with groundnut in moist and dry savannas of Nigeria, and how these characteristics relate to increased symbiotic nitrogen fixation and productivity.

Amaral M. Chibeba is a Mozambican studying at *Universidade Estadual de Londrina* in Brazil. His research topic addresses symbiotic effectiveness of indigenous Bradyrhizobia strains and strategies to maximize the contribution of BNF on soyabean.

Mazvita Chiduwa is a Zimbabwean woman studying at Murdoch University. Her research asks "if the interaction of the indigenous and exotic rhizobia in contrasting Zimbabwean soil conditions result in superior individuals worthy of use in inoculants".

Michael Kermah is Ghanaian studying at Wageningen University. His interest is identifying opportunities for sustainable intensification of grain legumes relating to crop productivity, food security and livelihoods of smallholder farmers in northern Ghana.

George Mwenda is a Kenyan studying at Murdoch University. His research examines rhizobial competition and N nutrition on nitrogen fixation in *Phaseolus vulgaris*. Before departing for Australia he collected over 130 isolates for detailed characterization.

Edouard Rurangwa is a Rwandan studying at Wageningen University. His research explores options to enhance biological nitrogen fixation by soyabean and common bean in smallholder farming systems of Rwanda.

7.5 **Affiliated Advanced Training**

One unexpected benefit was the attraction of graduate students funded by others but working on project topics. In effect, the project served as a nucleus to other academic and donor bodies seeking to anchor graduate students to useful purpose. In total 29 affiliated students (of which 48% women) were divided between four African and three European universities. Research topics were unequally divided among Legume Agronomy (56%), Rhizobiology (38%) and Technology Dissemination (6%). Seven of these students attended Wageningen University. Two African universities in West Africa (KNUST in Ghana and Ahmadu Bello University in Zaria, Nigeria) were particularly effective in attracting eleven of these affiliated students. In many cases, these students were attracted to the project having already completed required coursework and graduated ahead of those fully sponsored. Laboratory and field research costs were often covered by N2Africa, while tuition and stipends were covered by others. These additional students have helped to embed research on BNF technologies within African universities. N2Africa, by providing a clear research framework and opportunity for doing research, attracted many students from different universities.

Table 7.3: The outcomes of training in BNF technology dissemination employed in different countries by N2Africa over four years.

Country	Lead Facilitators	Country Trainers	Lead Farmers	Training Ratio 1	N2Africa Farmers	Training Ratio 2
DRC	0.5	2	579	290	19,200	33
Ghana	1	3	60	20	35,010	584
Kenya	2	3	108	36	37,464	347
Malawi	1	4	753	188	30,817	41
Mozambique	1	2	704	352	48,851	69
Nigeria	1	3	347	116	44,580	128
Rwanda	0.5	4	150	38	19,940	133
Zimbabwe	1	3	320	107	24,000	75
Overall	8	24	3021	126	259,862	86

7.6 Training Farmers in BNF Technologies

The project adopted an ambitious target of training 225,000 small-scale farmers in grain legume enterprise and BNF technology over four years (Section 3). This goal was undertaken in a three-step fashion where a cadre of Master Trainers from all eight countries were trained early in the project at a single event (Koala *et al.*, 2010), then each of these Master Trainers returned to their respective countries and trained a legion of Lead Farmers in practical application of BNF technologies and farm liaison, and each of these Lead Farmers conducted grassroots training of their group members and neighbours (Figure 7.3), resulting in a small army of farmers empowered with practical knowledge of BNF technologies. Eight Lead Facilitators, comprised of N2Africa professional staff, started this process by commissioning 24 Country Trainers. These Country Trainers each then trained on average 126 Lead Farmers over four years, resulting in 3021 Lead Farmers with expertise in legume agronomy and BNF (Table 7.3). The ratio of Lead Farmers trained per Master Trainer varies strongly between countries. Fewer Lead Farmers were trained in Ghana, Kenya and Rwanda, but more intensively compared to the other countries. Table 7.3 also presents the total number of farmers reached per country, resulting in strong variation in number of farmers reached per lead farmer. Ghana, Kenya and Rwanda showing relatively high numbers and reflecting the different strategies adopted to reach the farmer within the various countries. 'Farmers reached' means farmers who have received a technology package with supporting instruction and extension materials. These packages are not necessarily provided through the lead farmer, but could be distributed by the co-operator or farmer association directly at field days or through other channels. In some countries (e.g. in Ghana and Mozambique) farmers are reached through associated projects that do not necessarily use the lead farmer concept. The Lead Farmer is primarily responsible for the demonstration plots and extension provided through these. These groups typically consist of 20 to 30 farmers. Furthermore, up to the third

Figure 7.3: Master Trainers learned to interpret root nodulation patterns.

year the Master Trainers trained more Lead Farmers every year, while previously trained Lead Farmers continue their grassroots efforts allowing for the project farmer training target to be reached. This affectively doubles the number of Lead Farmers active in the project, which would change the statistics and provide a more 'realistic' number of farmers reached per Lead Farmer. Clearly, the skills of the Master Trainers, and their selection of Lead Farmers are critical to this larger training effort.

7.6.1 **Training Master Trainers**

A Master Trainer workshop (Training of Trainers) on legume enterprise, BNF technologies and technology dissemination was organized in September 2010 for agricultural extension workers and NGO staff in Kisumu, west Kenya (Koala *et al.*, 2010). The workshop was conducted for five days and attended by twenty-four participants from eight countries in Africa, namely; Democratic Republic of Congo, Ghana, Kenya, Nigeria, Malawi, Mozambique, Rwanda and Zimbabwe (Figure 7.4). Women comprised 33% of these trainees. The facilitators of the workshop were drawn from N2Africa and other partner organizations. Training was organized into nine modules (Table 7.4) and included lectures, open discussion, practicals and field visits.

Understanding the project's plans for technology dissemination and the role of newly commissioned Master Trainers within it were central to workshop roundtable discussion and mentoring by facilitators. By the end of the workshop, each participant formulated a strategy and schedule for training Lead Farmers in their respective countries. While participants appreciated the workshop, they commented that it did not contain sufficient information on legume agronomy beyond inoculation and that the training schedule of nine modules with afternoon field visits and practicals was crowded. The incomplete representation of women among both participants and facilitators was noted and formed the basis of a general agreement that 50% of the Lead Farmers must be women. Overall, this workshop laid the foundation for more accurate advice to farmers in BNF and legume-based enterprises by participating dissemination agents and established the basis for stepwise rapid amplification of technical training in BNF technologies and other needed areas. The training manual and practicals developed for this workshop (Woomer, 2011) are available on the Project's website (www.n2Africa.org) to parties interested in conducting similar activities.

Table 7.4: The nine training modules covered over two weeks at the N2Africa Training of Master Trainer Workshop in 2010.

Module 1: Nitrogen in small-scale agriculture
Module 2: Legumes and their uses
Module 3: Rhizobium bacteria as a biological resource
Module 4: The legume-rhizobia symbiosis
Module 5: Rhizobium inoculants
Module 6: Inoculation of legumes
Module 7: The response to legume inoculation
Module 8: Grain legume enterprise in small-scale farming
Module 9: Mobilizing communities toward BNF technologies

Figure 7.4: Country Trainers visiting a field demonstration in Kenya, September 2010.

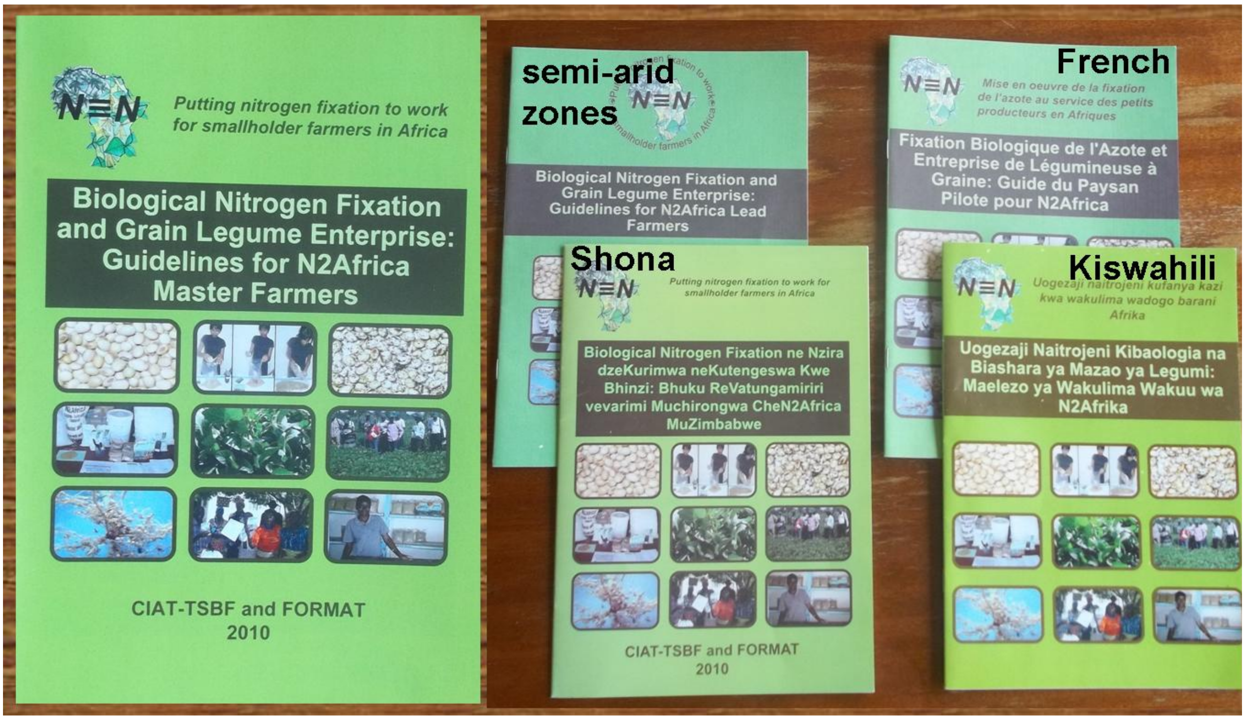


Figure 7.5: Lead Farmer training was supported by distribution of a 16-page booklet that was later adapted to semi-arid areas and translated into five additional languages (Hausa and Rwandese not shown).

7.6.2 Training Lead Farmers.

Upon return home, Country Trainers were tasked with developing Lead Farmer training. Trainers had earlier noted that for dissemination a bridging document was required to simplify the more difficult technical messages. This booklet (Woomer, 2010) was printed for use in the bimodal rainfall areas of East and Central Africa, and then adapted to semi-arid conditions (Figure 7.5). Project partners translated it into five additional languages. Nearly all the Lead Farmers were provided copies of these guidelines. Trainers were also required to assemble the initial BNF technology dissemination tools for use the next growing season and to base part of the training upon plans for field demonstrations. This required input from legume agronomists, rhizobiologists and dissemination specialists but was presented in a manner that developed skill sets required by Lead Farmers to effectively serve farmers at the grassroots level (Table 7.5). Training consisted of lectures, open discussions, field and workshop practicals. Over time, additional emphasis was placed upon post-harvest handling and marketing. On average each Country Trainer coached 126 Lead Farmers over four years, usually as teams of two or three and in groups of 30 to 40, but this varied among countries. While some countries offered multidisciplinary, two-day training with multimedia facilities, others elected to conduct half-day training on specific field protocols; both considered being Lead Farmer training.

Table 7.5: Skills checklist for N2Africa Lead Farmers.

- ☑ Access improved varieties of grain legumes
- ☑ Identify common crop pests and diseases
- ☑ Access special fertilizers needed for grain legume production
- ☑ Diagnose major nutrient deficiency symptoms
- ☑ Recommend appropriate intercropping and rotation strategies
- ☑ Practice and explain basic soil conservation measures
- ☑ Identify effective and ineffective legume root nodules
- ☑ Select a proper inoculant for cultivated legumes and store it properly
- ☑ Inoculate legume seed with rhizobia and test response to inoculation
- ☑ Design, install and interpret needed diagnostic field tests
- ☑ Evaluate the need for lime, P fertilizers and starter N by grain legumes
- ☑ Adjust recommendations and product information to local conditions
- ☑ Identify and adhere to grain legume industry standards
- ☑ Handle legume grains in a manner that protects their quality
- ☑ Establish and supervise community-based seed production
- ☑ Assist in the design and operations of collective marketing operations
- ☑ Explain the goals and activities of the N2Africa project
- ☑ Respond to the special needs of women farmers
- ☑ Expand the services offered to members of grassroots farmer groups
- ☑ Contact local extension officers and researchers for special advice

7.6.3 Grassroots Training

Training of Lead Farmers by Country Trainers set the stage for grassroots farmer training. This training bears special importance within N2Africa because it is the number of households trained in BNF technologies and the benefits they accrue that are the measure of success in the Project's Vision of Success. Exposure to BNF technologies involves learning by doing, where farmers receive a small technology package for testing on their own farms. This is the dissemination package mentioned earlier that is distributed to and evaluated by participating farmers. Typically, this tool contains seed of an improved legume, a small amount of fertilizer, legume inoculant if needed and user instructions, and is intended for planting onto plots of 100 to 250 m^2 producing 10 to 50 kg of grain. Interested farmers are invited to sign up for participation and to assemble on a given day, sometimes to assist in the installation of larger field demonstrations. After receiving the technology package and brief instructions structured along crop management scheduling (Table 7.6), they return to their farms and install it. Often the seed, fertilizer and inoculant technologies are included in larger and more diverse demonstrations that in turn serve as foci for farmer field days and other promotional events. In this way, farmers learn from their own efforts and are exposed to a wider variety of options in nearby demonstrations.

Table 7.6: A summarized checklist for farmers' better management and increased BNF by grain legumes.

- ☑ Plan ahead and prepare the land well (seven main points)
- ☑ Bean and soyabean growers inoculate (three main points)
- ☑ Plant on time and at the proper spacing (four main points)
- ☑ Closely manage and monitor crop development (six main points)
- ☑ Harvest on time and clean to industry standards (five main points)
- ☑ Protect grain quality and market your crop (five main points)

One feature of this approach is that it is not intensively monitored because of the huge numbers of participating farmers. One requirement is that each season every farmer receiving the dissemination package be new to the project so that the sign-up sheets directly reflect upon the number of households exposed to BNF technologies. A less obvious but very important training mechanism is mentoring by Lead Farmers as they visit with farmers in their respective groups and communities (Figure 7.6).

Figure 7.6: Nodulation assessment by a woman Lead Farmer during a follow up visit to BNF Technology Tests in their community.

Some controversy raised during these dissemination campaigns is whether or not this approach constitutes the distribution of free inputs that may impede the adoption of the technology and inhibits growth of commercial input supply. By distributing only small packages of inputs once this concern is circumvented. In addition, farmers are contributing to project technology testing by contributing land and labour, and risking crop loss from failed efforts. Finally, the farmers receiving these inputs are the main source of legume seed the following season through the two-for-one agreements established with many farmer groups. What happens next is very important. Those farmers that seek to expand grain legume production must access inputs in subsequent seasons. Whether and how they do so determins the larger impact of the project. This is why the project also includes an agrodealer training component.

7.7 Working with Agrodealers

N2Africa seeks to stimulate the marketing of BNF technologies to small-scale farmers, an activity that necessarily involves both local agrodealers and their suppliers. Toward this end, it is important that agrodealers understand which products are available, how and when they are used, and where to obtain them. Among these products are seed of legume and legume intercrops, specialized blends of fertilizers that lack nitrogen and rhizobial inoculants. N2Africa worked with agrodealers in two ways. First we offered training in the handling and marketing of BNF products and accompanying technologies to agrodealers in conjunction with technology dissemination (Turner and Woomer, 2012) and later a survey was conducted among both trained and untrained agrodealers to determine the penetration of BNF technologies through commercial channels (Section 3).

Table 7.8: Summary of agrodealer training in BNF technology products.

Country	Agrodealer training	
	Events	Agrodealers
DR Congo	1	18
Ghana		
Kenya	2	71
Malawi	1	13
Mozambique		
Nigeria	1	30
Rwanda	1	34
Zimbabwe		
Total	6	166

7.7.1 Agrodealer Training

Training workshops on legume and inoculant technologies were organized for agrodealers in all participating countries (Turner and Woomer, 2012). This training was originally scheduled to begin in Year 2 with 90 stockists trained per year, but was delayed until Year 3 due to the need to prepare training materials and align wholesale suppliers, local stockists and farmer groups. Pilot training was conducted in Kenya in November 2011 and the tested training materials and schedule distributed to Country Coordinators for local adoption. In total, 166 agrodealers were trained at 6 workshops (Table 7.8) using a combination of lectures, product demonstrations and group discussion (Table 7.7).

Table 7.7: Agrodealer training topics and general impressions.

Training topic	*Participant impressions*
1) Agro-dealership and grain legume enterprise	*Revealing, include legumes in local product demonstrations*
2) BNF technologies and new farm input products	*Interesting but supplies of these new products are not reliable*
3) Biological nitrogen fixation and legume inoculants	*Informative but inoculants are not widely available*
4) Legume seed quality, handling and marketing	*Concern over policies related to expired stock*
5) Fertilization, pest and disease management of legumes	*Products available but accompanying product information needed*
6) Recommendations and product testing at the grassroots level	*Too technical for agrodealers, requires extension support*
7) Agrodealer networks and coordinating business activities	*Useful, network organizers should be more involved in training*
8) Agrodealer business training and certification	*Opportunities for business training exist but are not widely available*

Agrodealers were also advised to consider opportunities addressing women customers by distributing promotional fertilizers and seeds to stimulate demand by poorer households and then marketing inputs in smaller quantities. Some crops, including grain legumes are under the control of women farmers, and access to input by the groups should not be ignored. In addition, business relations may be cultivated through local women's groups to help coordinate seasonal demand for BNF technologies.

In many cases, agrodealers were asked to develop specific plans to advance BNF products following their training. This was reinforced by the presence of representatives from input suppliers who took orders for seed, inoculants and fertilizers not containing nitrogen. Many of these agrodealers pledged to expand their product range and increase sales of BNF technologies, and to share their learning with their customers and farmers. Several key issues were raised during discussion at these training workshops. Legume seed, specialized fertilizers and legume inoculants are best marketed at the same time and place, and promoted through customer information. Legumes should be included in the agrodealer roadside variety demonstrations that are often dominated by maize. The availability of product information from suppliers must improve so that agrodealers can make better marketing decisions concerning new BNF technologies. Farmer groups can work with input suppliers and local agrodealers to better market BNF products as a service to their members. Lastly, means must be found to reduce the risks of expiry when stocking legume inoculants with the best case being replacement of expired stock. When agrodealers consolidate their orders for seed, fertilizer and inoculants, they enjoy greater bulk discounts and obtain their stock in a timely, better planned manner. Wholesale suppliers sent representatives to some of these training workshops so that agrodealers could place orders for the upcoming growing season. Because of their importance as local distributors in input supply chains, these and other agrodealers were surveyed during the project's Early Impact Assessment, with the results presented in Section 3.

7.8 **Educational and Extension Resource Support**

The N2Africa Training Unit based in Nairobi was tasked to provide training, educational and extension resource materials to support the full scope of N2Africa activities, and to make these resources applicable and available to others outside the project. First, a series of laboratory protocols were produced to assist the Rhizobiology Team and then captured in a single manual (Woomer *et al*., 2010) for use in technician and student training. Two main mechanisms were developed to achieve impacts beyond the project; linking N2Africa to African institutions and professional bodies, and developing web-based support to facilitate information flows within and beyond the project. In this way, educational and learning materials supported project staff and reached other related programs and organizations, raising understanding and practical skills in legume and inoculation technologies. Bimonthly publication of an electronic newsletter, the Podcaster, and posting on a regularly updated website served as effective mechanisms to distribute this information.

7.8.1 **Linkage to African Institutions and Professional Bodies**

From its onset, N2Africa interacted with two key professional bodies, the African Association for Biological Nitrogen Fixation and The Regional Universities Forum, two well-established organizations that benefit immediately from the project's technical and scientific training materials. In addition, N2Africa complemented two sister projects funded through the Bill & Melinda Gates Foundation; Tropical Legumes II as a provider of improved legume seed and COMPRO for its expertise in the regulation and testing of innovative agricultural inputs. Furthermore, N2Africa complemented the efforts of AGRA's Soil Health Program (Sanginga *et al*., 2013; Turner, 2012). N2Africa collaboration expanded beyond these organizations as the resource materials were used by a wider audience.

7.8.2 **African Association for Biological Nitrogen Fixation (AABNF)**

Through working with N2Africa, members of AABNF are being reoriented toward more practical, problem solving and commercially oriented approaches. AABNF was established in 1976 as a professional membership organization devoted to advance BNF among the continent's farmers and research and development communities. Prof. Nancy Karanja, Director of the Nairobi MIRCEN and N2Africa partner, currently serves as its President. TSBF-CIAT and the University of Nairobi co-hosted the 17th biennial AABNF conference in November 2012 where AABNF and N2Africa issued a joint call for action which states "Biological nitrogen fixation remains a key to securing improved food and nutritional security and improving land and crop management among African smallholder farmers" and raised the following seven priorities:

- A centralized Africa rhizobium germplasm bank is needed. Different African laboratories hold over 2000 isolates, but many small collections of rhizobia in Africa are at risk of becoming lost.
- The performance of rhizobial isolates requires fuller assessment. Bio-prospecting must be systematic and include the full range of African ecologies and symbiotic legumes.
- A range of legume inoculant products are available but not widely distributed nor available to most farmers. Policies must be developed that permit the free flow of inoculants between countries.
- Advances are being made in selecting legume varieties and land management options with greater potential for nitrogen fixation. A better understanding of plant/microbe interactions and an integrated approach to soil fertility will improve our ability to explain yield variability in cropping systems.
- Crop residue management strategies that recycle BNF gains vary for different grain legumes and cropping systems. A better understanding of farmer management of soil heterogeneity allows more relevant research into legume cropping and residue management.
- Basic elements of inoculation, legume agronomy and data analysis require due attention and systematic enquiry. Concern exists that BNF mechanisms and systems other than those involving symbiotic legumes continue to be under-researched and insufficiently promoted.
- Rhizobiology and BNF findings must be better communicated at several levels. There should be a focus on building the capacity of farmers and service providers to respond to obtaining seasonal weather conditions and climate change. The importance of freer movement of isolates and inoculant across borders must be explained to policymakers and better facilitated.

7.8.3 **The Regional Universities Forum**

The Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) is an association of 29 Faculties of Agriculture in East and Southern Africa that recognizes the important and largely unfulfilled position that universities occupy in contributing to the well-being of African small-scale farmers. N2Africa participated in the Third RUFORUM Biennial Conference during September 2012 where it exhibited and distributed its training materials and made direct contact with university lecturers responsible for instruction in soil microbiology, BNF and legume agronomy. In addition, six N2Africa graduate students presented research papers.

7.8.4 **Alliance for a Green Revolution in Africa (AGRA)**

This organization promotes a uniquely African Green Revolution that transforms agriculture into a highly productive, efficient, competitive and sustainable system that assures food security and lifts millions out of poverty. From its very onset, N2Africa has worked closely with AGRA, particularly its Soil Health Program (SHP). A joint implementation plan was developed and representatives agreed to attend each other’s meetings to reinforce activities. N2Africa provided the SHP with all field and laboratory protocols and extension and farmer training materials. In addition, N2Africa forged direct links with AGRA grantees, providing them with recommended legume varieties, inoculants and site-specific fertilizer recommendations. Through its Market Access Program, AGRA promotes functioning markets that provide reliable outlets for farm produce, with activities in Ghana, Kenya and Malawi that opened markets for farmers working with N2Africa. Further, Anne Mbaabu, Director of the AGRA Market Access Program serves on the N2Africa Steering Committee to ensure our collaboration on our mutually beneficial activities.

Tropical Legumes II (TLII). This project specializes in increasing the productivity and availability of grain legumes in Africa, including N2Africa's four target crops, bean, cowpea, groundnut and soyabean (Dashiell *et al.*, 2010). By the start of N2Africa, TLII had multiplied over 1.2 tons of improved grain legume seed and offered its best varieties. Thus a natural partnership was borne. TLII provided N2Africa with most of the improved grain legume seed used in its first season. N2Africa provided TLII guidelines for assessing BNF under inoculated field conditions. TLII advised N2Africa on seed multiplication approaches. Finally, N2Africa tested its elite rhizobial strains on TLII varieties and recommended inoculants for use in breeding and seed multiplication. This partnership was facilitated by close physical proximity of staff as researchers from both projects shared the same buildings in Kenya, Malawi, Mozambique and Nigeria. From this partnership a suite of general principles emerged: work with agrodealers and seed companies wherever possible, work within our respective mandates in a mutually beneficial manner, exchange information on the best performing varieties each year, coordinate M&E on seed multiplication activities. Because of this close working relationship, N2Africa partners were never short of quality legume seeds.

7.8.5 **COMPRO**

COMPRO is short for *"Institutionalization of quality assurance mechanism and dissemination of top quality commercial products to increase crop yields and improve food security of smallholder farmers in sub-Saharan Africa"*. It works with research institutions and regulatory agencies in six countries including Kenya and Nigeria. Target agricultural input products monitored by COMPRO include rhizobium inoculants, and its independent testing reinforces N2Africa's quality assurance. LegumeFix widely used in West Africa showed no contaminants and high numbers of viable rhizobia. BIOFIX produced in Kenya and used throughout the East and Southern African sub-regions contained contaminants but also effectively nodulated host legumes. COMPRO has expertise in product regulation and policy formulation and N2Africa has experience in technical quality control procedures and working relations with legume inoculant producers that are mutually beneficial. Working relations are further strengthened by both project's coordinators operating from the same research complex in Nairobi.

7.8.6 **Other collaborations**

Other working relationships formed during the course of N2Africa activities. The Humidtropics Program adopted Legume Intensification as a key entry point and included DR Congo, Kenya and Rwanda among its Action Sites. Our field activities overlapped by one year (2013) and our BNF technologies and some cooperators moved into Humidtropics. The International Fund for Agricultural Development established a commodity-marketing project that provided opportunities to N2Africa cooperators in DR Congo and Malawi. The Africa Soil Health Consortium is a new project "contributing towards radical change" in the understanding and use of Integrated Soil Fertility Management techniques in sub-Saharan Africa. Three N2Africa scientists sit in its advisory committee and they and others assisted in the development of extension-level information on grain legumes and BNF Technologies.

7.9 **International Communication**

7.9.1 **Project Information and Web-based Support.**

The N2Africa newsletter (The Podcaster), and website, *www.n2africa.org*, was led by the team at Wageningen University.

7.9.2 **The Podcaster**

This N2Africa newsletter presents short news stories and announcements from a diverse range of project partners including farmers, students, researchers, country coordinators, project leaders and donors. Its content is aimed toward the general public, published electronically every two months and distributed to a mailing list to 1480 subscribers. It is also available through *www.n2africa.org* where it is accessible as individual news stories or download in printable, complete format. To date, 24 issues were released.

7.9.3 **www.n2africa.org**

The N2Africa project distributes its achievements and offers web-based support over its website *www.n2africa.org*. The site has two zones; a publicly accessible area that promotes and offers a wide range of information about the project, and the intranet accessible only to project partners to submit reports, post scheduled activities and monitor progress. Over one thousand visitors access the public zone per month, with 70% visiting for the first time. It consists of project news and announcements, milestone reports and publications, thematic and student progress, project staffing and links to related sites.

A feature with growing popularity and recognition is video sharing. N2AFRICATV (www.n2africa.tv) offers a large number of video documentaries, covering the various aspects of the project from research, to delivery and dissemination and capacity building. It contains a series of videos under the rubric of “Introduction to People and Places”, a series that covers thematic aspects: “I Eat”, “I Sell”, “I Store”, “I Understand”, video documents that provide instruction, explain theory and methods as well as approaches adopted by the project, like the Development to Research approach. Also some video documents that report on specific studies, like the nutrition study carried out in Ghana, are included. Also available on the web is N2MAP; a tool that makes use of using Google Maps to provide access to video, still images, survey- and experimental data, and by doing so provides overview of all the location where N2Africa has been implemented.

The N2Africa intranet is organized using a Content Management System, enabling authorized users to both submit and access content and in this way share content with others in the project. It also reminds members of their upcoming tasks and overdue submissions.

7.9.4 **Interactive Decision Support**

The project was originally intended to post interactive support on key N_2 fixation methodologies and techniques, the maintenance and trouble-shooting advice for scientific equipment used in BNF research, and to adjust extension materials for download based upon local conditions. It was later decided that this was not feasible. Some spreadsheet utilities were developed to assist in calculating inoculant dosage, analyse the results from standardized quality control tests, assist in calculating net benefits from BNF technologies, and to project the impacts from farmer adoption of BNF technologies. Work that remains includes preparing user manuals and combining these utilities into a single menu-driven program. N2Africa maintains a repository where all training and extension materials can be downloaded.

8 Country Strategies and Achievements

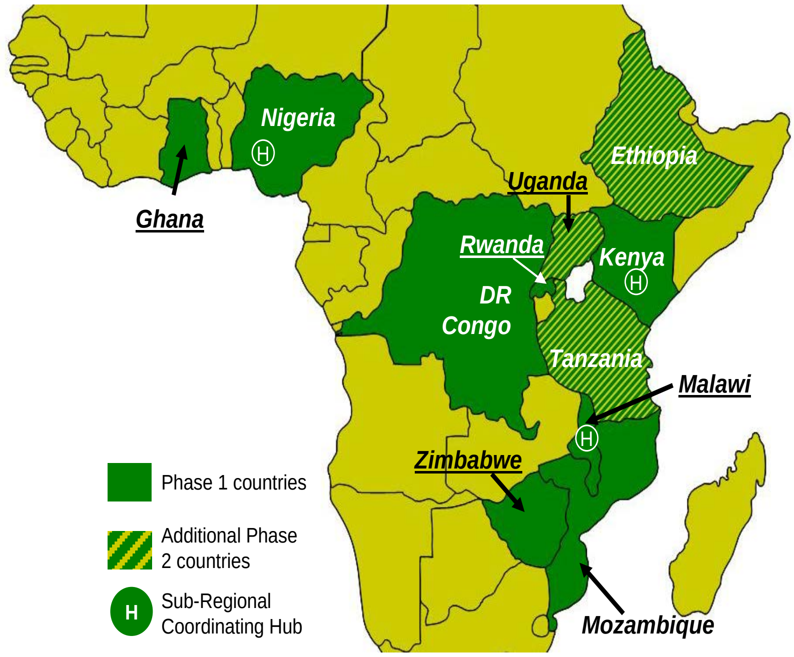


Figure 8.1: N2Africa Countries and Regional Hubs.

The original plan for N2Africa was to operate in eight countries through three sub-regional Hubs (Figure 8.1). At the inception workshop it was decided that the full suite of tasks relating to legume agronomy, rhizobiology, BNF technology dissemination and capacity building should take place in each country. Thus instead of working through regional hubs, teams were organized in each country, led by a Country Coordinator. While all countries had capacities in field agronomy, skills and facilities in rhizobiology and BNF technologies were wanting. Therefore, capacity building focused on training and upgrading of laboratory facilities, geared to specific country requirements. Similarly, while each country had similar responsibilities with regard to technology dissemination, differences in institutional setting determined country partnership arrangements. The strategies and achievements of each of the countries are described below.

8.1 DR Congo

Table 8.1: Summary of N2Africa outreach activities in DR Congo.

Outreach action	Total
Number of New households	19452
Number of on-farm demonstrations	78
Inoculants packets distributed	23,317
Legume seed distributed	7 tons
Fertilizer distributed (Tons)	11 tons
Master farmers trained	119
Extension manuals distributed	217,899

The N2Africa Action Site in DR Congo was South Kivu Province. The project reinforced technical capacities in legume agronomy and rhizobiology through training conducted in Kenya. Concurrently, a new rhizobiology laboratory and greenhouse were constructed at the newly founded Kalambo Agricultural Centre. Rhizobiology research was led by the Catholic University of Bukavu and conducted by both MSc students and supervised technicians. BNF technology dissemination was organized by the N2Africa DRC team comprised of N2Africa staff and local partners, assigned a BNF technology dissemination target of 17,500 households (Table 8.1). Moreover, N2Africa laid important groundwork through the support of multi-stakeholder partnerships backstopped by several regional and local research and development organizations. At the onset of the project, input value chains were poorly organized, with neither inoculants nor phosphorus fertilizers commercially available. Soils are relatively fertile along the northern axis of the mandate area, whereas they are rather poor towards the southern part of the province. Despite its reliable bimodal rainfall, poverty is widespread in South Kivu, in large part because of insecurity following a series of civil wars. Nonetheless, N2Africa found willing partners because of the huge potential of legumes in farmers' maize, cassava and banana cropping systems.

Extensive legume agronomy trials were conducted at 11 locations over seven consecutive cropping seasons. Most of these examined bean and soyabean varieties and their response to imported fertilizer and inoculants, but others explored options for legume intercropping and climbing bean staking. Namsoy 4 (=SB24), SC Squire, SC Saga, and Imperial were the most suitable soyabean varieties in South Kivu. These varieties are early maturing, high yielding, have varying degrees of resistance to Asian soyabean rust and have ready markets. Climbing bean variety AND 10, Musale, Kiangara and bush bean varieties CODMLB001 and Marungi were the best in term of grain yield, biomass accumulation, tolerance to heavy rains, resistance to pests and diseases and most popular in the market. Both bean and soyabean respond well to P application on younger volcanic soils, but little response was observed on highly weathered acidic soils to the south. Soyabean responds well to rhizobia inoculation but this is less the case for beans. Early attempts to introduce fodder legumes had little impact, as a majority of farmers do not own livestock.

Through N2Africa, rhizobiology was initiated in South Kivu. The DRC Rhizobiology team isolated and characterized 107 indigenous rhizobia and entered them into the N2Africa database. Of these, 15 candidate elite strains of soyabean were identified in the greenhouse based upon symbiotic effectiveness and competition with native populations. Little was done on screening rhizobia for bean. Field-testing of identified soyabean strains is now underway. The laboratory has established quality control procedures for imported inoculants and is experimenting with inoculant production at small scale. A promising peat carrier was identified at Walungu, southwest of Bukavu, and is being tested.

BNF technology dissemination was a major achievement in DR Congo, conducted through partnership with the local non-government organizations, particularly DIOBASS, SARCAF and PAD. This partnership has grown over time and now BNF technologies and grain legume enterprise ranks high in their rural development agendas (Figure 8.2). Regular training, widely installed field demonstrations and farmers field days contributed to this success (Table 8.1). Fourteen community seed production groups continue to produce improved varieties of beans and soyabean under the leadership of partner organizations. Thirty women groups were trained on legume value addition and continue to market their products in and around Bukavu. Farmers are aware of the benefits of soyabean inoculation but commercial availability remains limited, in large part because agrodealers are not well organized. Nonetheless, four agrodealers in Bukavu now market BNF technologies where none were available before. Finally, N2Africa partners are now linking with other projects, including Harvest Plus and Humidtropics, as a means of sustaining impacts.

Country Coordinator: Dr Fred Baijukya.

Figure 8.2: N2Africa staff and partners at a training workshop conducted at the Kalambo Agricultural Centre, north of Bukavu, South Kivu.

8.2 **Ghana**

The N2Africa Project extended improved legume and inoculant technologies to a large number of smallholder farmers in northern Ghana. The country has a well-developed agro-input supply and distribution chain and efficient agrodealer networks except that rhizobium inoculants were not available from suppliers. The presence of a number of certified seed producers and functional agricultural extension service facilitated outreach activities. The Rhizobiology team was composed of scientists from Soil Research Institute and the College of Agriculture and Natural Resources (CANR), KNUST. The legume agronomy and dissemination campaigns were executed by the CSIR-Savanna Agricultural Research Institute, a number of NGO's (ACDEP, UrbAnet, EPDRA, ACDI/VOCA) and Ministry of Food and Agriculture (MoFA), respectively. Major constraints to the implementation of the Project were inadequate rainfall and lack of institutional capacity for the production and distribution of *Rhizobium* inoculant. This was compensated by the importation of LegumeFix inoculants from the UK.

The Legume Agronomy team conducted 54 trials in seven districts. These trials identified legume varieties with greatest yield potential, and highest response to inoculation. The best widespread performing varieties of soyabean were TGX 1448-2E, Salintuya-1 and Jenguma, with Jenguma being the most preferred variety by farmers. However, performances of cowpea and groundnut varieties were site specific. For instance cowpea variety Songotera generally out-yielded the rest of the varieties at some locations while Zaayura and Apagbaala produced significantly higher yields at others. The same for groundnut variety Samnut 23, performing well in Bawku West district, while Manipinta performed best in Kassena Nankana East municipal. Generally the Samnut genotypes (Samnut 22 & Samnut 23) obtained from TLII-Nigeria out-yielded the local groundnut varieties and they were equally more resistant to *Cercospora* leaf spot disease. Strong responses to inoculation with Legumefix and phosphorus application were observed, but the results were highly variable across sites as observed in all countries. Conducting these trials in three successive growing seasons allowed lessons learnt from the previous season to impact positively on the design of next season's dissemination tools. A large database resulted from these agronomic trials.

Steady progress was made with rhizobiology from the start. Rhizobium bioprospecting led to the recovery of 190 isolates, which were characterized and entered into the N2Africa *Rhizobium* Database. Of these, 53 isolates were screened in the greenhouse for symbiotic effectiveness on soyabean compared to USDA 110, a widely used industry standard, leading to the identification of 22 highly effective isolates, but none outperformed the reference strain. Quality control procedures for imported inoculants were established.

BNF technology dissemination was extensive and largely successful. A total of 773 demonstrations were established on-farm across the mandate area during the 2012 cropping season alone, 518 using soyabean, 175 with cowpea and 80 with groundnut. This dissemination campaign reached 35,010 households over three years (Table 8.2). A striking development was the widespread acceptance of LegumeFix inoculants and farmer's willingness to pay for them. Also by disseminating improved seeds to farmers, varietal preferences of farmers have shifted toward high yielding varieties and a reduced tendency of selling off their best seeds as grain, reducing shortfalls the following season. Additional farmers are now being reached through the activities of AfricaRising and the Adventist Development and Relief Agency as these large organizations have included BNF technologies within their developmental agendas. Agrodealer training workshops conveyed new knowledge on inoculant suppliers and handling, and accompanying legume technologies including hazards associated with pesticides. Commercial distribution of imported inoculants is being actively promoted but with an eye toward developing domestic production in the near future.

Table 8.2: Summary of N2Africa outreach activities in Ghana over four years.

Outreach action	Total
Number of new households	35,010
Number of on-farm demonstrations	1167
Inoculants packets distributed	707 kg
Legume seed distributed	57 tons
Fertilizer distributed (tons)	22 ton
Master farmers trained	606
Extension manuals distributed	1200

Country Coordinator: Prof. Robert Abaidoo

8.3 Kenya

Table 8.3: Summary of N2Africa outreach activities in west Kenya over four years.

Outreach action	Total
Number of new households	37,464
Number of on-farm demonstrations	355
Inoculants packets distributed	59,231
Legume seed distributed	223 tons
Fertilizer distributed (tons)	320 tons
Master farmers trained	226
Extension manuals distributed	48,938

Kenya was well positioned to participate in N2Africa from the onset. It had commercialized input supply, including manufacture of inoculants, through well-organized marketing channels, and a strong demand for grain legumes from buyers. Both Legume Agronomy and Rhizobiology teams were well placed at the Maseno Agricultural Research Centre and the Nairobi Microbial Research Centre, respectively. Its greatest assets were the farm organizations eager to work with the program in the west Kenya Action Area, and the bimodal rains that offer two reliable growing seasons per year. Ready access to N2Africa Headquarters in Nairobi also expedited matters. Two difficulties were a weak national extension service and no available commercial seed of its two target grain legumes, climbing bean and soyabean.

The Legume Agronomy team conducted field trials for seven consecutive growing seasons at eight representative sites. It demonstrated which legume varieties had greatest yield potential, responded to inoculation and were pest and disease resistant. Soyabean 19 from IITA, cv. Squire from SeedCo and climbing bean cv. Kenya Tamu were the best performing varieties. Legumes responded to P-application at most sites but greater yields were achieved through a combination of nutrients. The tight sequence of growing seasons allowed for useful feedback between the on-farm adaptive research and the larger BNF technology dissemination campaigns. Positive information flows also resulted in improved plant spacing of soyabean and modified climbing bean staking systems.

Rhizobiology actions were led by the MIRCEN at the University of Nairobi through its experienced technicians and graduate student research. A nationwide campaign of rhizobium bio-prospecting led to the isolation and characterization of 387 rhizobia. A stepwise screening program was conducted that included greenhouse effectiveness, competition in potted soil and field performance and led to the identification of six candidate elite strains; NAK 84, 115 and 128 for soyabean and NAK 5, 67, 157 for bean. The program's Rhizobium Database was developed by the MIRCEN team. The opportunity to work with MEA Ltd. on its BIOFIX inoculant led to improved production operations (mechanical mixing of injected packets), quality assurance (a system for independent testing), overall quality (from less to greater than 10^9 rhizobia per gram) and establishment of a return policy for expired inoculants. Two difficulties remain however, our search for a superior carrier to sugar factory filter mud was inconclusive and the counts of contaminants remain high, even after double autoclaving the carrier prior to injection. Next MEA plans to examine the feasibility of shifting production from carrier injection to bulk mixing and automated packaging.

BNF technology dissemination led to widespread adoption of grain legume enterprise. Outreach activities are summarized in Table 8.3. Field demonstrations, farmer field days and grassroots training was conducted among 26 farmer groups and local NGOs by a cadre of Master Farmers armed with a variety of extension materials (Figure 8.3). Several developments signal our success in technology dissemination. Sympal, a fertilizer blended specifically for symbiotic legumes was developed by N2Africa and commercialized by MEA Ltd. After technology testing, households seeking to enter into legume enterprise were provided with fertilizer and inoculant on credit and guaranteed markets at local collection points connected to Promasidor Ltd., a major food processor in Kenya. Most of the inputs delivered through outreach were extended to these progressing farmers on credit through their farm organizations and repaid as grain for collective marketing (77% of fertilizer and 84% of inoculants). In addition to the directly facilitated (new) households, satellite partnership reached an additional 17,098 farms belonging to Promasidor out-growers and One Acre Fund clients, but these households were not as closely monitored.

Local agrodealers were trained and aligned with specific farmer groups to assure continuity of input supply. Seeds were bulked through a combination of approaches, with the 2-for-1 payback approach being most successful. Promotion of grain legume processing led to the establishment of three factories in west Kenya producing soymilk and protein fortified flour, as well as numerous community activities and local "kiosk" shops, with soymilk tea, yogurt and crispy snacks most popular. Starting with only 720 kg of improved legume seed distributed to farmer groups in 2010, only three years later 726 t of soyabean worth $457,000 were collectively marketed and 181 tons of seed retained for the following season.

Figure 8.3: Participants in the first Master Farmer training in west Kenya. These Master Farmers went on to conduct grassroots training, organize field events, train additional Master Farmers, monitor program activities, establish input shops and market collection.

N2Africa will continue to work through its established commercial linkages between input manufacturers, farmer cooperatives, local agrodealers and top-end buyers of grain legumes. The widespread distribution of small, free BNF technology packages has led to huge returns in rural communities and reduced Kenya's dependence upon soyabean importation (though marginally). Farmers undertaking BNF technology testing and pilot production provide labour and land, that could be devoted to other proven enterprises, in return for the inputs received, while assuming all the risk from poor weather or underperforming results. Important is that after initial exposure to "free" BNF technologies, farmers be provided opportunity to invest in these technologies at a larger scale. The Nairobi MIRCEN was a key partner in Rhizobiology across the program, completing all its scheduled tasks in a timely manner and will continue to curate the N2Africa rhizobium collection.

Country Coordinator: Dr Paul L. Woomer. Rhizobiology Leader: Prof. Nancy K. Karanja.

8.4 **Malawi**

N2Africa worked in seven administrative districts of Malawi through partnerships with non-governmental organizations, farmers associations, agrodealer networks and the Ministry of Agriculture and Food Security. Field activities unfortunately missed the 2009-2010 rains but operations accelerated in subsequent years. The main areas of interest were promotion of legume and inoculant technologies through participatory research and delivery and dissemination of the tested technologies through Lead Farmers and their grassroots groups. The project had a dynamic monitoring and evaluation component, which guided research findings into the delivery and dissemination system and vice versa. The capacity of the Rhizobiology Laboratory in the Department of Agricultural Research Services at Chitedze was enhanced through training and equipping the lab to meet the many tasks of rhizobial research and production. The interlinked contributions of agronomic research, rhizobiology and technology delivery, in conjunction with the Lead Farmer approach, led to improved legume production in Malawi

All four N2Africa target grain legumes, cowpea, groundnuts, soyabean and common bean were evaluated in Malawi. Fertilizer response was studied for all four legumes, but inoculation response was only examined for the latter two hosts. The legume grain yields did not respond strongly to P-based fertilizers. Inoculation of soyabean with rhizobia demonstrated consistent response, with a 53% increase in yield obtained during the 2011-2012 rains (Figure 8.4). In contrast, common bean did not respond consistently to inoculants, and additional research is needed to understand where and when an inoculation response can be expected. Chitala groundnut was identified as a variety tolerant to groundnut rosette and was steady substituted for the susceptible CG7 during project field activities.

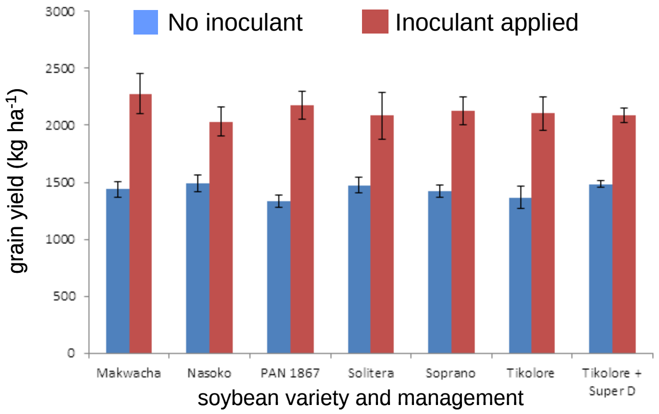


Figure 8.4: A consistent response to inoculation by several soyabean varieties in Malawi.

N2Africa supported the Chitedze Rhizobiology Laboratory through technician training and upgrading of laboratory and greenhouse facilities. Laboratory upgrading included the installation of equipment, including an incubator, large autoclave, multi-meter, microscope, and a filter for the lamina flow hood. Standard strains of rhizobia were received and used as positive controls for strain effectiveness studies and later cultured for inoculants. The laboratory isolated 170 rhizobia from six different legume hosts, but effectiveness testing is incomplete due to late renovation of the laboratory. Difficulties were also experienced in conducting MPNs so N2Africa relied more upon the Response-to-Inoculation Tests in potted soils. The pilot inoculant plant produced 15,000 fifty-gram packets in the past year. Now the Department of Agricultural Research Services seeks partnership with the private sector to boost inoculant production in the country. The plans are to build a new inoculant production factory, train technical staff and up-scaling production and quality control assurance. One of the interested investors in inoculant production is Agro-Input Supply Limited, which is expected to start commercial inoculant production in 2014.

N2Africa Delivery and Dissemination activities were conducted through several partners including World Vision, Catholic Relief Services, the National Smallholder Farmers Association of Malawi, Agro-Input Suppliers Association of Malawi and the Department of Agricultural Extension Services in the Ministry of Agriculture and Food Security. These technology dissemination efforts are summarized in Table 8.4. N2Africa built capacity of these partners, training extension personnel and commissioning Lead Farmers, leading to grassroots training, BNF technology demonstrations, farmer tours and numerous radio and extension messages. Training in legume marketing, processing and nutrition were also undertaken. For example, N2Africa facilitated development of four marketing associations for Catholic Relief Services by linking members to two commodity exchange networks (ACE and AHCX). In total, N2Africa worked with 66 communities reaching 31,329 households, considerably beyond the initial target of 25,000.

Table 8.4: BNF technology dissemination goals achieved in Malawi.

Outreach activity	Total
Households reached	31,329
Legume seed distributed (tons)	30.5
Lead farmers trained	1176
Extension staff trained	217

Country Coordinators: Dr Anne Turner and Barthlomew Chataika.

8.5 Mozambique

In Mozambique, N2Africa benefited from close collaboration, in particular with Technoserve and CLUSA. Activities were conducted in the central and northern part of the country with assistance of the Tropical Legumes II Project for grain legume assessment. Through 23 adaptive trials across four provinces several excellent soyabean varieties (e.g. TGx 1740-2F and TGx 1904-6F from the IITA TGx soyabean lines and SC Storm) as well as groundnut varieties (cvs. Mamane, Chitala and Nametil) were identified. These varieties were advanced through 378 on-farm trials. Accompanying BNF technologies included inoculation, SSP application, adjusted planting dates and row spacing. Management recommendations were based upon agronomic trials where soyabean responded strongly to inoculation and P addition (Figure 8.5). Groundnut responded to P application and higher plant populations. In a rotation trial, maize yield following soyabean increased by 30%.

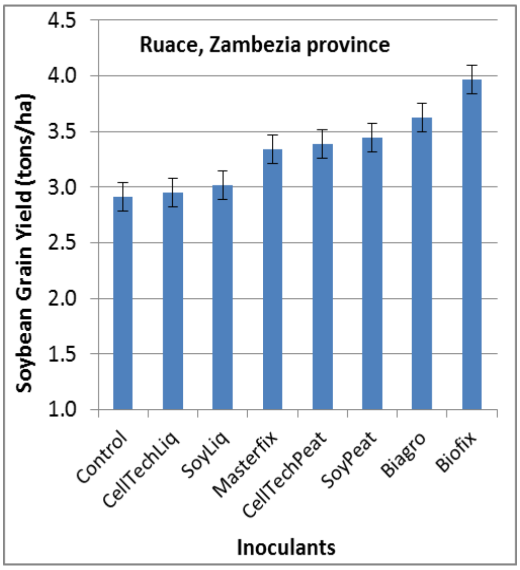


Figure 8.5: Effect of several inoculant products on soyabean grain yield.

The N2Africa project had no access to Microbiology facilities in Mozambique. Similarly, it has no inoculant production facility so evaluation of several imported inoculants became central to its BNF technology adoption. Inoculants consistently improved soyabean grain yield by 350 to 700 kg ha^{-1} when averaged across sites with Biagro and Biofix treatments producing best yields (Figure 8.6). As inoculants cost only \$6 ha^{-1}, farmers cannot lose by using inoculants in Mozambique!

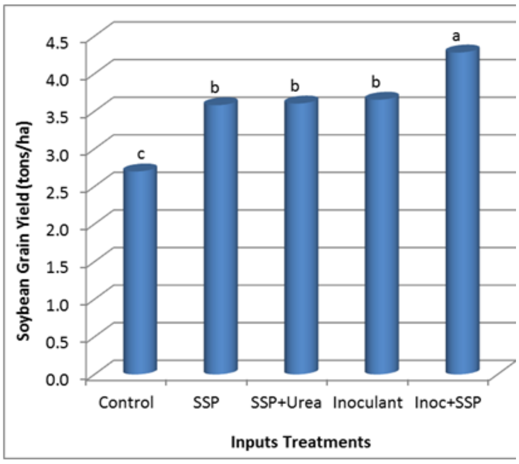


Figure 8.6: Grain yield of soyabean variety Storm in response to various input applications.

N2Africa partnered with well-organized farmers associations and grain legume initiatives and established strong partnerships including Technoserve, Cooperative League of USA (CLUSA), IKURU, and the National Agricultural Research Institute (IIAM). It established 812 demonstration plots on farmers' field (≈ 30% of these farmers were women) to reach 48,851 households. Distribution of inputs to participating farmers included 385 tons soyabean seeds, 8 tons of groundnut seeds, 13 tons of SSP and 2.6 tons of imported inoculants (Table 8.5). Most of these inputs were paid for through the various partner programs; approximately 5% of this amount was supplied directly by the Project as contribution to the demonstration and other D&D activities

Table 8.5: Summary of N2Africa outreach activities in Mozambique over four years.

Outreach action	Total
Number of households	48,851
Number of demonstrations	812
Inoculants distributed (kg)	2,600
Legume seed distributed (tons)	393
Fertilizer distributed (tons)	13
Master farmers trained	3164

The project also trained 3164 lead farmers and they in turn, trained their association members to facilitate scaling up of the technologies. Female farmers were encouraged to participate in the project through training and demonstration on soyabean home processing and utilization aimed to enhance protein and energy quality of traditional foods. Sixty-five (65) field days were organized across the project impact zones during the project period to promote and create awareness of improved legume technologies. The gains made in the application of BNF technologies and grain legume enterprise will continue through the activities of our rural development partners in Mozambique (Figure 8.7).

Country Coordinator: Dr Stephen Boahen with assistance from, Henriques Colial, Artur Fernando and Nelito Rosario

Figure 8.7: Farmers evaluate different soyabean and groundnut varieties in Mozambique.

8.6 **Nigeria**

Implementation of the N2Africa Project in Nigeria benefited substantially from the past investment in legume technologies across the northern part of that country. Here short duration cowpea and promiscuous soyabean varieties were developed and promoted by IITA. Agricultural institutions in Kaduna and Niger States, the national extension service and NGO SG2000 were quickly incorporated into dissemination activities. Responsibilities for research were shared between local universities (Bayero and Ahmadu Bello Universities) and the national Institute of Agricultural Research (IAR). Later, research this was extended to the Southern Guinea savannah by the Federal University of Technology of Minna. Northern Nigeria has over 500,000 ha of soyabean and well-organized local development organizations, including women and marketing groups.

Cowpea, groundnut and soyabean are the mandate legume crops in northern Nigeria and the growing season extends from June to November. Partners conducted agronomic investigations on variety selection, inoculation response and crop management for four consecutive seasons with 17 local government collaborators representing three agro-ecological zones of the Guinea savanna. This work led to the development of several crop and area specific technology packages incorporating legume varieties, P- and micronutrient fertilization, inoculants where needed and improved crop populations and arrangements. Positive response to P fertilizer is widespread, but more localized best practice required participatory trials. Agronomic findings were incorporated into best practice demonstrations plots in farmers' fields for farmer evaluation the following season. Areas with strong response to inoculation stimulated farmers' interest in securing legume inoculants as well as community-specific preferences toward improved legume varieties. *Striga*-resistant cowpea IT97K-449-35 was preferred in many areas and especially Kano State, while under other conditions where *Striga* is not that prevalent (e.g. in Kaduna and Niger States) higher yielding and fodder producing varieties IT90K-277-2 and IT99K-573-1-1 were favoured. Many of the newer TGx soyabean varieties form IITA are now replacing those introduced several years ago.

Early in the project, laboratory upgrading was performed at the Institute of Agronomy Research in Zaria, and technical training provided by N2Africa. Thereafter, about 600 isolates of rhizobia were prepared from root nodules of the mandate crops as well as other legumes in natural ecosystems and farmers' fields, and 250 of these were sufficiently characterized for inclusion into the N2Africa Rhizobium Database. Many of these isolates outperformed the commercial standard USDA 110 in sterile culture under greenhouse conditions. Delays in expanding greenhouse facilities delayed more complete characterization. Field evaluation trials are on-going to compare the effectiveness of locally selected rhizobia with introduced strains including elite strains from Kenya and additional commercial standards. Three strains from Nigeria, NAN 24, NAN 109 and NAN 177, are included among the candidate elite strains of the project for further investigation. Because Nigeria does not produce commercial legume inoculants, LegumeFix inoculants were imported from the UK. Seasonal quality control tests were put in place. Nigeria will soon produce Nodumax inoculants within the new IITA Business Incubation Platform, with production of 300,000 packets, sufficient for 50,000 ha of soyabean, planned for 2014.

Dissemination of legume technologies was led by the respective Agricultural Development Projects (ADPs) in the three states covered by N2Africa: Kaduna, Kano and Niger. Further Sasakawa Global 2000 (especially for Kano State) and the Niger State Agricultural Development and Mechanization Authority played an important role. Dissemination approaches and tools were formalized into N2Africa protocols following seasonal assessment meetings involving community feedback and local training, demonstration plots, field days, and media events conducted. In total, 46,300 households were provided opportunity to test BNF technologies over four years using 34 tons of seed multiplied from new legume varieties (Table 8.6). This exceeds the original household target of 37,500 by 23%. Many groups of farmers, especially women, were trained in legume processing technologies. Despite these successes, participants have raised concern about the unavailability of legume inoculants through commercial channels. The Project is trying to address this through engaging the private sector.

Table 8.6: Summary of BNF technology dissemination activities in Nigeria.

Outreach Activity	total
Households reached	46,300
Legume seed deployed (t)	34
Inoculant deployed (kg)	70
Fertilizer deployed (t)	1274
Legumes established (ha)	797

An important aspect of farmers accessing legume inoculants and other accompanying grain legume technologies is the willingness of local agrodealers to carry these products as commercial suppliers emerge. Training of agrodealers on inoculant handling and marketing was conducted and these stockists linked to pioneer commercial distribution of inoculant through existing input distribution networks of the Seed Project and Company Ltd. In Niger State three suppliers were recruited and commercial distribution of inoculants tested during the 2013 growing season. N2Africa provided the product for free to suppliers with agreement on the retail price and proceeds used to improve storage facilities and purchase inoculant the following season.

Over four consecutive years, N2Africa worked successfully to disseminate innovative legume technologies in northern Nigeria. Farmers are enthusiastic about opportunities to improve and expand grain legume enterprise including the adoption of BNF technologies. A signal of this success is the official request from agricultural authorities of Jigawa State to commence similar activities there, an effort to be led by SG2000.

Country Coordinators: Prof. Abdullahi Bala and Dr Mahamadi Dianda.

8.7 **Rwanda**

Rwanda was among the first countries where dissemination and adaptive research campaigns kicked-off soon after the launch of N2Africa. N2Africa relied upon CIALCA to mobilize the partners and identify initial research goals. The Government of Rwanda was supportive in terms of waiving duty on imported fertilizers, inoculants and laboratory equipment. The Rhizobiology Laboratory of the Rwanda Agricultural Board (RAB) at Rubona was re-established after its destruction during the genocide in 1994. Once again it produces inoculants! Four soyabean varieties that are high yielding and meet farmers preferred attributes were officially release and commercialized. Newly released bean varieties were also promoted and adopted by farmers. Our dissemination partners remain committed to advancing legume technologies within their programs, following the increased demand of both soyabean and common bean in the local markets.

Legume agronomy activities were coordinated by RAB-Rubona over seven consecutive growing seasons at thirteen locations, including evaluation of varieties, inoculants and fertilizers. Four soyabean varieties (SC Saga, SC Squire, SC Sequel and cv Maksoy (SB24) performed well, proved resistant to Asian soyabean rust and offered attributes preferred by the farmers and buyers. Climbing bean varieties Gasirida and RWV1348 performed best, as did bush bean varieties RWR 1668, RWR 2076 and RWR 2245. Soyabean responded to inoculant and P application in most sites. Good bean yields were obtained with combined application of organic manure and P fertilizers. Farmers in the southern Rwanda adopted planting of cassava at wider row spacing to accommodate more beans in the intercropped system. Tree legumes *Leucaena pallida*, *Leucaena diversifolia, Calliandra* and *Alnus* were promoted with farmers in northern Rwanda as source of fodder and stakes for climbing bean. One of the constraints to agronomic efforts was the low capacity of the facilities at RAB-Rubona to handle, process and analyse plant samples.

The RAB-Rubona, working closely with the Nairobi MIRCEN, led Rhizobiology actions. Bio-prospecting campaigns resulted in isolation and characterization of 259 rhizobia, which are part of the project's Rhizobium Database. From these, 15 soyabean isolates and 13 bean isolates were highly effective and advanced for further testing in potted soils and in the field. The Rhizobiology Laboratory established a pilot legume inoculant plant producing 44,500 eighty-gram packets of inoculant for soyabean and common bean over the past year. These inoculants contribute to the promotion of soyabeans by the Ministry of Agriculture and Animal Resources. These inoculants are also marketed through selected agrodealer shops. RAB and Rwanda Bureau of Standard are working to develop the national quality control protocol for biofertilisers and are being advised by scientists from N2Africa.

Table 8.7: Summary of N2Africa dissemination activities in Rwanda from 2010 to 2013.

Outreach action	Total
Number of demonstrations	104
Number of new households reached	20061
Inoculants deployed (kg)	175
Soyabean seed distributed (kg)	2017
Climbing bean seed distributed (kg)	4184
Bush bean seed distributed (kg)	5618
Fertilizer distributed (kg)	10000
Seed multiplication sites	53
Master farmers trained	1735
Facilitators trained	36
Extension manuals distributed	10,550
Radio shows conducted	17

N2Africa dissemination interventions in Rwanda were conducted in the Eastern, Northern and Southern Provinces, from which 5 districts (mandate areas) and 13 communities (action sites) were selected for outreach activities. Dissemination activities started in February 2010 with 150 farmers demonstrating the successful use of legume inoculants from Kenya. During the second and third year, BNF technologies were mainly focused on improving bean and soyabean production through use of seed of improved varieties and multiplying these improved varieties through community-based seed multiplication (Table 8.7). More recently, commercialized production of improved seed through contractual agreement with Seed Co was initiated. Farmers readily adopted the use of mineral fertilizers in soyabean and beans. Additional dissemination activities demonstrated rotational benefit of target legumes with maize and intercropping of bush bean and improved cassava varieties. Maize yields increase by 15-20% following climbing bean and soyabean respectively. Intercropping of bean with cassava at modified spacing provides 45% greater yields compared to currently practice. The

PICS-bag technology, which reduces crop loss to storage pests, was tested successfully and the bags are now locally produced. In total 104 demonstration plots were established in 13 action sites. Thirteen agro dealers were trained on inoculant handling and marketing. Partner organizations participated in conducting national performance trials throughout Rwanda and four of the best soyabean varieties were released in July 2013.

Country Coordinator: Dr Freddy Baijukya. Field Liaison Officer: Speciose Kantengwa. Rhizobiology Leader: Mathilda Uwizerwa and Cassien Byamushana.

8.8 Zimbabwe

The project commenced in the 2010-2011 season in seven administrative districts in Zimbabwe. Strong collaboration was forged with different research partners in legume agronomy and rhizobiology. In its dissemination of BNF technologies, N2Africa worked in close partnership with the government agricultural extension services, AGRITEX, and with several NGOs: Community Technology Development Organisation (CTDO), Cluster Agriculture Development Services (CADS) and Lower Guruve Development Association (LGDA). These partnerships have developed well over the years; through extensive training within partner organizations resulting in expanded farmers' capacity in legume production. Plans are being developed to continue these efforts at smallholder empowerment including greater focus upon household nutrition and women's enterprise.

Agronomy trials were conducted for three subsequent seasons in the seven intervention districts. During all three seasons, the rainfall distribution was below average, which affects the interpretation of agronomic trials. The best fertilization strategies in sandy soils require a combination of both P-based fertilizers and organic manures. Single super phosphate (SSP) is cheaper among the P-based fertilizers for legumes and has the highest potential for adoption. Soyabean varieties SC Squire and SC Saga are among the most suitable soyabean varieties in Zimbabwe; both varieties are high yielding and rust-resistant. Common bean response to inoculation was poor, although some varieties like Speckled Ice showed potential. The variety Cardinal was high yielding in most farmers' fields, yet it is not the most popular variety on the market.

The available varieties for groundnut and cowpea are few; moreover cowpea seed was usually a mixture of varieties and land races. However, all the CBC line varieties do well - even on the granitic sandy soils - compared with the farmers' own germplasm. Input trials for groundnut provided a positive response to gypsum application because the developing pods need to take up calcium directly from the soil, something that was eagerly adopted by farmers. Natal Common, a well-adapted groundnut variety that is high yielding and has high market demand, was disseminated to smallholders. Farmers are familiar with the variety but through agronomy trials, demonstration plots and distribution of certified seed, they observed its characteristics directly. Part of this preference results from planting better quality seed as their recycled seed of the same variety had degraded.

The Soil Productivity Research Lab (SPRL) at Marondera conducted the rhizobiology work. Bioprospecting was delayed in favour of other activities and only 29 rhizobia were isolated and characterized. The best performing isolates were then tested in the field, together with the strain usually used for the production of inoculants and some of the best strains from Kenya. The commercially available *Bradyrhizobium japonicum* strain MAR 1491 (= USDA 110) is probably not the best in terms of symbiotic effectiveness. MAR1305, MAR1306, MAR1497 and MAR 1515 show better yields, but performance was also related to agro-ecological region. These inconclusive results show the need for further collection and evaluation of strains. Meanwhile the production of inoculants at SPRL continues with 86,300 one hundred gram packets produced over the last year. A quantity assurance program is in place with carriers, broths and final products all being routinely inspected.

Basic access to legume seeds, P-based fertilizers and inoculants by smallholder farmers was in place at the project's onset, but most farmers were unaware of the improved management and production that creates demand for these inputs. Focus was therefore placed upon farmer training and further advancement of input supply channels. Similarly, buyers were in place to purchase grain legumes meeting industry standards, but their influence had not yet reached remote households. Legume production becomes more sustainable as new legume technologies and market demand reach more farmers. For this purpose, training of agrodealers was initiated in 2012 and now linkages between agrodealers and suppliers of seed, P-based fertilizers and inoculants have strengthened.

Table 8.8: Summary of BNF technology dissemination activities in Zimbabwe.

Outreach Action	Total
Total number of households reached	24,525
Total number of lead farmers trained	1,263
Legume inoculant packages distributed	2,593
Legume seed distributed (t)	27.5
Fertilizer distributed (t)	74.2
Number of demonstration plots established	1,257
Number of field days conducted	61

Community-based legume seed production was facilitated by N2Africa and yielded very positive results as farmers now produce seed of very good quality and generated income in the process as they are distributed to other farmers (Table 8.8). This approach was proved an avenue through which farmers can access affordable quality seed, while others engage in profit-making enterprise. Opportunities were not limited to soyabean alone as in Guruve and Mudzi districts many farmers moved into commercial production of common beans and groundnuts, respectively. Much of this success is the result of stronger linkage to markets and value-adding legume processing promoted through local NGO partners. Local processing of materials proved feasible at both the household and commercial levels.

Country Coordinator: Judith de Wolf.

9 Bridging activities in Ethiopia, Tanzania and Uganda

In 2011, N2Africa was requested by the foundation to explore the opportunities to establish partnerships in Ethiopia, Tanzania and Uganda. Activities started in January 2012 through a supplementary grant. We met with key government stakeholders in each country and held stakeholder workshops where we identified target regions and crops, based on high potential for intensification of legume production or for expansion of their area. In addition, we focused on building collaboration with partners working to strengthen the value chain through developing input and output markets, and strengthening farmer organizations.

As a follow up on the stakeholder workshop several pilot-activities were established. In Ethiopia we multiplied seed of improved varieties of soyabean, chickpea, common bean and faba beans. In addition, through partnership with Hawassa University, we established multi-locational trials to test the need for rhizobial inoculation with chickpea on farmers' fields and under farmers' management. These trials indicated a response to inoculation in chickpea and made us decide to use inoculants in chickpea demonstrations (Figure 9.1).

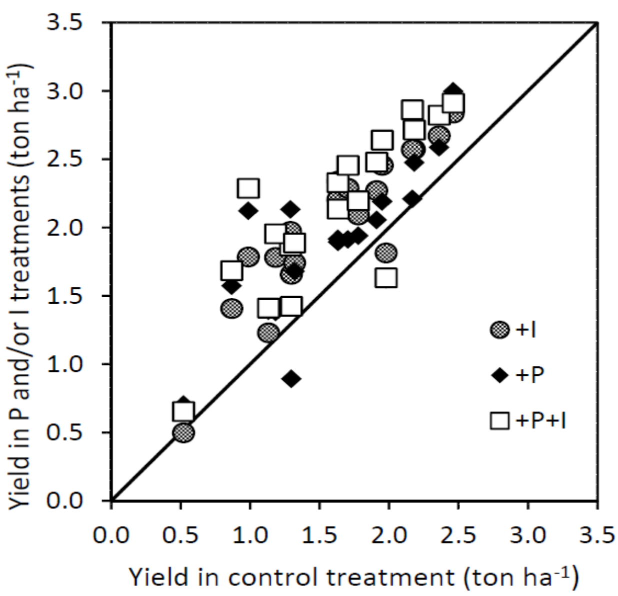


Figure 9.1: Response of chickpea grain yield to inoculant and/or P-fertilizer in Wolaita, Ethiopia

In Uganda and Tanzania, we multiplied seed of soyabean, groundnut and of bush and climbing bean varieties of common bean. In addition, the Catholic Relief Services funded 'Soya ni Pesa' project in Tanzania was supported with agronomic training and the supply of soyabean inoculants. The seed-multiplication activities in all three countries ensured a sufficient stock of seed for widespread demonstrations.

To benefit from the momentum created through the stakeholder workshops and pilot-activities, additional funds were granted to bridge the period between 2012 and 2014 and to bring the three countries up to speed in anticipation of N2Africa Phase II. Country teams were set up with the appointment of a country coordinator and research assistants. The country coordinators focused on establishing partnerships with NGOs for dissemination of legume technologies and with national agricultural research centers for agronomic research. Carrying out dissemination and research activities with these partners in the bridging year allowed us to test the different partners and to tackle some of the logistical challenges in the early stages of project management. Teams were also equipped with the necessary tools for project implementation, with specific focus on rhizobiology laboratories and greenhouse infrastructure next to the purchase of vehicles and motorbikes.

A baseline survey was carried out to characterize local farming systems in the target areas. Areas were sampled based on differences in agro-ecological potential and market access, to determine the impact of improved legume technologies on farmers in different environments. First results from Northern Tanzania indicate that over 90% of the farmers grows beans (in sole or intercropping), but that the use of mineral fertilizers and organic inputs in beans is low (Table 9.1). A report with a compilation of the results of survey in all countries is expected mid-2014.

Table 9.1: Average field size and use of mineral fertilizer and organic inputs in beans in Northern Tanzania

Crop type	Average field size (ha)	Mineral fertilizer	Organic inputs
Beans (n=59)	0.57	12%	19%
Beans&other (n=25)	0.65	24%	28%
Maize&beans (n=327)	0.61	35%	35%
Maize&beans&other (n=115)	0.89	36%	45%

As mentioned above, NGOs and research partners were involved in dissemination and research activities. Demonstrations on farmer's fields were used to create awareness on N2Africa technologies and to evaluate these technologies under farmers' practice. In Ethiopia, demonstrations on common bean, soyabean, chickpea and faba bean were established on farmer's field in Amhara (36 demonstrations), Oromia (72 demonstrations), SNNPR (36 demonstrations) and Benishangul-Gumuz (36 demonstrations). The demonstrations consisted of two high-potential varieties with and without inputs (P-fertilizer and rhizobium inoculant). In Northern Tanzania, demonstrations with climbing bean and bush bean were established in four districts (Arumeru, Moshi Rural, Hai and Lushoto), with 20 demonstrations per district. Each demonstration consisted of three varieties with and without inputs (P-fertilizer, rhizobium inoculant and cattle manure). In Southern Tanzania we focused on the continuous support of the 'Soya ni Pesa' project through technical advice and further multiplication of groundnut and soyabean seed. In Uganda, demonstrations with climbing bean (160 demonstrations), groundnut (147 demonstrations) and soyabean (32 demonstrations) were established in Eastern, Northern and Southwestern Uganda in two seasons (2013A and 2013B). Each demonstration consisted of three varieties with and without inputs (P-fertilizer, rhizobium inoculant and cattle manure).

Agronomic research was carried out through agronomy trials. Each country had a variety and an input trial of all target legumes in the country. A number of promising varieties was tested without and with inputs (P-fertilizer and/or rhizobium inoculants). The input trials tested the effect of P and/or K-fertilizer, rhizobium inoculants and cattle manure, separately and in combination. Interestingly, the agronomy trial on climbing bean in Eastern Uganda showed a strong response to inoculants (produced at Makerere University) compared with the control (Figure 9.2), which has been rare in N2Africa so far. A milestone report on the results of the demonstrations and agronomy trials is expected mid-2014 and will form the basis for designing further research and dissemination activities.

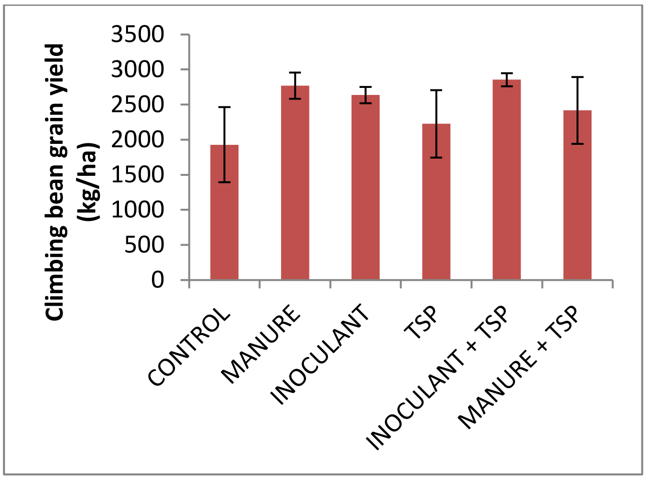


Figure 9.2: Climbing bean grain yield (variety NABE12C) without and with inputs (cattle manure, rhizobium inoculant produced at Makerere University, TSP and their combination)

All in all, the activities in the bridging phase in Ethiopia, Tanzania and Uganda leave us well-prepared for a flying start of N2Africa Phase II in these countries.

10 Lessons learned from implementing the N2Africa Development to Research project

In this section we reflect on some key lessons learned from the implementation of N2Africa and the actions taken to address challenges and shortcomings as they arose. We focus mainly on the eight original target countries. Lessons learned are categorized in terms of project management & implementation, rhizobiology, agronomy and development & dissemination.

10.1 Lessons learned on project management and implementation

The N2Africa project proposal written through series of workshops with many of the key partners who participated in the project. Yet it was not possible to include all potential partners in discussions before it was clear that the project would be funded. This meant that many of the detailed discussions as to the roles of different partners and the modes of operation and the development of partner contracts were done after the start of the project, inevitably leading to delays in the first season of implementation. The timing for delivery of milestones in the original proposal was the same across the whole project, whereas different regions had cropping seasons at different times of the year. This created problems in reporting on milestones at the same time for all countries.

N2Africa is a complex project in terms of organisation, administration and operation as well as technical perspectives. The project initially planned to operate from three hubs, one in each region: West Africa, East & Central Africa and southern Africa. Our idea was that countries that share similar same agroecological conditions and have similar agricultural systems also share similar problems and thus benefit from sharing experience and solutions generated. At the inception workshop it immediately became clear that planning for operations in each country was complex and required multiple partners. Further, each country wished to develop independent laboratory infrastructure for rhizobiology and not rely on a central hub. Project planning and implementation was therefore done in each country separately. The coordination office at CIAT in Nairobi was responsible for coordination and reporting, with support from IITA overviewing activities in West Africa and Mozambique and Wageningen University in data and information management.

Many staff had dual responsibilities. Most country coordinators were also responsible for one of the work-streams (‘Research and Data’, ‘Delivery and Dissemination’, ‘Rhizobiology’, ‘Agronomy’ and ‘Monitoring and Evaluation’). Perhaps inevitably this often led to greater attention being focused on immediate, country-level challenges and less attention to the work-stream responsibilities across countries, or *vice versa*. This is one of the primary reasons for N2Africa moving to a more federal structure where all necessary skills are developed in each country with a central team providing leadership, coordination and specialist support.

N2Africa relied on many partners both for the research and the development related work. Inevitably for such a large project there was some staff turnover and occasionally consultants helped to bridge the gap while new staff were appointed. We were fortunate to experience fairly minimal turnover of staff in implementing partner organisations which contributed greatly to continuity in project implementation. Only in few instances were we forced to terminate our working relationship with partners. These cases all occurred in the first year and all involved failure to provide adequate technical and financial reports, or in one case because adequate the organisation did not have adequate financial controls in place.

10.2 Lessons learned from a technical perspective

10.2.1 Dissemination and Delivery

N2Africa had ambitious targets for the number of farmers to be reached. This led to pressure from the start of the project to implement dissemination activities. N2Africa relied heavily on development and outreach partners (NGOs and government research and extension services) for the widespread testing of technologies. Most often partners were engaged through sub-contracts for implementing defined tasks and activities. This led to a rather standardised approach to dissemination. Earlier, we had anticipated that more attention would be focused on using and evaluating the approaches of different partners. This led to a weaker anchoring of dissemination of N2Africa technologies in development programs of our development partners or in government programs and initiatives than we had hoped for. N2Africa attracted fewer satellite partners than originally anticipated. The embedding of N2Africa approaches in the outreach of partners will be a focus in the next phase.

The lead farmer approach was used in most countries and proved to be a successful model for reaching out to farmers and in dissemination of N2Africa technologies. A training of trainers approach was used and was instrumental in equipping lead farmers and extension workers with appropriate knowledge and skills. The strategy to increase the number of lead farmers over time worked well. More rapid growth of the number of farmers reached can only be achieved by including additional partners or expanding the capacity and geographic coverage of the partners. Seasonal planning meetings were effective in coordinating activities of the outreach program and provided a good opportunity to bring together various partners along the value chain (especially input suppliers, retailers and buyers). Farmer organisations or community-based organisations provided strong entry points in those countries where such organisations were already well developed.

N2Africa technologies were of great interest to beneficiaries. Farmers were particularly interested in the seed of new varieties and in the inoculants. In most countries farmers do not apply mineral fertilizer to legume crop. If they can afford to purchase fertilizer, they are most likely to apply it to cash crops or cereal crops such as maize. Widespread, on-farm demonstration plots were instrumental in arousing strong farmers' interest in the technologies. These demonstration plots were simple, and so successful that farmers in several countries soon began to object to wasting land for control plots. At the same time, the control plot is key to learning about where the technologies work best, and the field-level constraints to successful performance of the technologies.

Ensuring effective input supply and linking farmers to markets were major challenges. As volumes of produce increased rapidly the lack of well-organised marketing channels was a barrier in some countries. As N2Africa moves into the next phase facilitating the development of vibrant legume markets is a major objective.

Women participation in the project differed between countries but also within countries. In the 2011-2012 season in Zimbabwe for example, the percentage of female Lead Farmers varied from 28% to 64%. Some partners actively involved women, increasing women's participation in the projects. Partners within a country can thus learn from each other to ensure participation of female farmers in all activities. In addition, the very pro-active attitude of Rwandan development organizations in terms of involving women can provide useful lessons to address gender inequalities in the future, especially for countries in which the 50% women participation was not achieved (see also Annex 7 on gender disaggregation of project beneficiaries).

10.2.2 **Monitoring and Evaluation (M&E)**

Monitoring and evaluation is key to learning from success, obstacles and failures across the project. Gathering of M&E data was delayed as plans were not in place before project activities were started. The need for reporting on a large number of activities demands substantial time and resources to be devoted to M&E, yet these were not adequately budgeted or built into contracts with sub-partners. Perhaps too much attention was devoted to the more routine aspects of M&E to satisfy the need for reporting on milestones, rather than on deeper learning.

10.2.3 **Rhizobiology**

Overall progress in rhizobiology was hampered by the lack of expertise in this area in many of the countries. Although many students and technicians were trained through N2Africa this remains a concern. Investments in equipment and greenhouse infrastructure took long to establish which contributed to delays. MSc and MPhil students conducted much of the research and produced very interesting and useful results. The PhD students funded through N2Africa have yet to finalize their studies. Better integration of the rhizobiology and agronomy research is required, through Need-to-Inoculate trials and MPN counts as part of the agronomy research to explain patterns of response to inoculation in farmers' fields. We learned that greenhouses in the tropics are not an ideal place for conducting rhizobiology tests, unless adequate temperature control is available to avoid excessively high daytime temperatures as well as shocks from cool night time temperatures in some seasons.

The target of having five elite strains in production by inoculant manufactures was not realized. Testing of elite strains to identify suitable candidates for including in inoculant production goes beyond testing of effectiveness on a few locations and needs to include tests of stability in the laboratory as well as in the pack for prolonged shelf life. This work can be best conducted in collaboration with inoculant producers, to assist, for example, in detailed characterization using molecular methods which are currently beyond the means of our partner laboratories. Some inoculant producers have expressed interest in evaluating N2Africa's rhizobial germplasm.

Activities to influence progressive policies on the availability, quality and cross-border movement of inoculants are continuing in collaboration with the COMPRO project. Two examples of progress are Kenya where a Biofertilizer Act is before parliament and Ghana where inoculant standards are being written into existing fertilizer regulations.

10.2.4 **Agronomy**

A key learning is that best management practices cannot be identified on the basis of few large ‘factorial’ experiments, but rather require simple trials replicated at many locations. It is often the agroecological context that is over-riding in determining the success of technologies. The simple ‘demonstration trials’ in which a few treatments were tested against a ‘control’ treatment (e.g. +P, +I and +P+I) proved to be a powerful approach. Farmers were able to evaluate the technologies using their own criteria. Whenever possible comparison with farmer practice in an adjacent field is also instructive. Farmer ‘field books’ were used to capture information on crop management which, together with soil analysis and spatial data, was used to understand the major factors that determined crop response to the treatments. In cases where ‘non-responsive’ soils were identified these were then investigated through glasshouse experiments to determine other nutrient deficiencies, often conducted by MSc students. These feedback loops need to be shortened in order to offer the farmer integrated solutions. More detailed on-farm agronomic experiments should be driven by learning from these demonstration plots.

Farmers integrate grain legumes into their farming systems in many different ways. For example, while it is common practice in East and central Africa to eat the tender leaves of beans and cowpea, this practice is not common in southern Africa. In some regions legumes are intercropped with annual and perennial crops: in others largely as sole crops in rotation with cereal crops. Some attention was paid to exploring novel approaches to cereal-legume intercrops and this deserves further attention. Farmers should be offered a basket of options that need to be tested in farmers’ fields for several seasons.

Legume varieties with the greatest capacity for BNF tend to be long-duration varieties that accumulate large amounts of biomass. Often these traits are not combined with high grain yield or the most-preferred grain types. In some cropping systems, such as the bi-modal rainfall environments the late maturity of long duration varieties can lead to delay in field preparation for the subsequent season.

The resistance to pests and diseases is often of key importance, particularly as crops become more widely grown (for example with soyabean rust). Monitoring of pests and diseases in all demonstrations and experiments would be advantageous but is often restricted by lack of staff trained in these skills.

Despite our best attempts, it is clear that more effort is needed to harmonize data collection and assure data quality standards to allow for cross-country synthesis of results.

11 Annexes

Annex 1. Contributors to the N2Africa Project

Headquarters and Core Staff

Abaidoo, Robert. IITA. Administrative supervisor and Ghana Country Mentor. Email: *R.ABAIDOO@cgiar.org*

Baijukya, Fredrick. CIAT-Kenya. Legume Agronomy Leader and DR Congo and Rwanda Country Mentor. Email: *f.baijukya@cgiar.org*

Bala, Abdullah. IITA-Nigeria. Rhizobiology Leader (through 2011). Email: *abdullahi_bala@yahoo.com*

Dashiell, Kenton. CIAT-Kenya. Project Coordinator (through March 2012). Email: *K.Dashiell@cgiar.org*

de Wolf, Judith. CIAT-Africa. Monitoring and Evaluation Leader and Zimbabwe Country Mentor. Email: *judithdewolf@gmail.com*

Lubbers, Marcel. Wageningen University. IT Officer and Database Manager. Email: *marcel.lubbers@wur.nl*

Franke, Linus. Wageningen University. Research Leader. (from September 2010). Email: *linus.franke@wur.nl*

Giller, Ken. Wageningen University. N2Africa Principal Investigator. Email: *ken.giller@wur.nl*

Huising, Elmo Jeroen. CIAT-Kenya. Project Coordinator. (from September 2012). Email: *j.huising@cgiar.org*

Mahamadi, Dianda. IITA-Nigeria. Rhizobiology Leader and Nigeria Country Mentor. Email: *M.Dianda@cgiar.org*

Odhiambo, Lorraine. CIAT-Kenya. Administrative Assistant. Email: *L.Odhiambo@cgiar.org*

Ronner, Esther. Wageningen University. Research Assistant and Case Studies Leader. Email: *esther.ronner@wur.nl*

Rufino, Mariana. Wageningen University. Research Leader. (through July 2010). Email: *m.rufino@cgiar.org*

Schilt, Charlotte. Wageningen University. Communication Officer and Editor of Podcaster Newsletter. Email: *n2africa.office@wur.nl*

Simmons, Alastair. Taskscape (UK). Contracted video production. Email: *Alastair.Simmons@taskscape.org.uk*

Turner, Anne. IITA-Malawi. Technology Dissemination Leader. Email: *A.Turner@cgiar.org*

Woomer, Paul L. CIAT-Kenya. Inoculant Delivery Specialist and Kenya Country Mentor. Email: *plwoomer@gmail.com*

DR Congo Country Staff

Barhebwa, Fidel. PAD/Kenyatta University. MSc student research (Legume agronomy) Email: *barhefide@yahoo.fr*

Chifizi, Adrien .CIAT-Congo. Field Assistant. Email: *adrienchifizi@yahoo.fr*

Chishibanji. Christiant. CIAT- Congo. Accountant. Email: *cishibazungu@yahoo.fr*

Irenge, Yves. CIAT-Congo. Country Administrator. Email *yvesirege@gmail.com*

Kulimushi, Faustin .CIAT-Congo. N2Africa Farm liaison. Email: *bkulimushi@yahoo.fr*

Mapatano, Sylvain. DIOBASS. Coordinator. Email: *mapatano_s@yhoo.fr*

Mongane, Dieudonne. CIAT-Congo. Farm liaison officer. Email: *masumbukomongane@yahoo.f*r

Ndusha, Bintu. UEA/University of Nairobi. MSc student researcher (Strain selection). Email *bintundusha@yahoo.fr*

Rukiranuka, Bienvenu. UCB/CIAT-Congo. Technician Rhizobiologist. Email *bienvenubaba2@yahoo.fr*

Sanginga, Jeanmarie. CIAT–Congo. Agronomist and Focal point. Email *jeamariesanginga@yahoo.fr*

Sika, Eric. UCB/Kenyatta University. MSc student researcher (P response to inoculation). Email: *ericsika@hotmail.fr*

Walangululu, Jean. UCB/CIAT-Congo. Head of Capacity building and rhizobiology. Email *walangululu@yahoo.fr*

Ghana Country Staff

Ahiabor, Ben. Agronomist, CSIR Savanna Agricultural Research Institute (SARI), Tamale, email: *bahiabor@yahoo.com*

Aidoo, Robert. M&E Specialist, College of Agriculture and Natural Resources, KNUST, Kumasi, email: *badubob@yahoo.co.uk*

Akley, Edwin, K. Farm Liaison Officer, Savanna Agricultural Research Institute, Tamale; email: *akleyk@yahoo.com*

Asamoah, Gideon. Laboratory Assistant, CSIR Soil Research Institute, Kumasi, email: *gasamoah97@yahoo.com*

Baalaa, Abraham. Field Technician, College of Agriculture and Natural Resources, KNUST, Kumasi email: *baalaabraham@yahoo.com*

Opoku, Andrews. Administrative Assistant, College of Agriculture and Natural Resources (CANR), KNUST, email: *andrewsopoku@yahoo.com*

Tetteh, Partey. Samuel, Data Entry and Management, College of Agriculture and Natural Resources, KNUST, Kumai, email: *sammtech147@yahoo.co.uk*

Teye, Jonathan. Field Technician, College of Agriculture and Natural Resources, KNUST, Kumasi, email: *jonathan_teye2000@yahoo.com*

Yahaya, Asieku. CSIR Savanna Agricultural Research Institute, email: *yasieku@yahoo.com*

Yemyoliya, Jonathan. Field Technician, College of Agriculture and Natural Resources, KNUST, Kumasi email: *yemyoliya@yahoo.com*

Kenya Country Staff

Chemwada, Moses. Kenya Soybean Farmers Association. Farm Liaison Officer. Email: *mosekive@yahoo.com*

Kaleha, Celister. Resource Projects Kenya. M&E specialist and farm liaison officer. Email: *kalehah@gmail.com*

Karanja, Nancy. University of Nairobi MIRCEN. Rhizobiology laboratory Director and student supervisor. Email: *nancy.karanja@cgiar.org*

Kisamuli, Stanley. University of Nairobi MIRCEN. Chief Laboratory Technician and Inoculant Quality Control Technician. Email: *stanley.kisamuli@gmail.com*

Kivanda, George. Kenya Soybean Farmers Association. Marketing specialist and farm liaison officer. Email: *kesofasoya@yahoo.com*

Mutegi, George. Murdoch University (Australia). Bioprospecting leader and PhD student researcher. Email: *mutegi@gmail.com*

Mulei, Welissa. CIAT. Data entry specialist and assistant editor. Email: *wmulei@gmail.com*

Mutegi, Edwin. CIAT-Maseno. Farm monitoring and evaluation. Email: *e.mutegi@cgiar.org*

Olwal, Josephine. CIAT Maseno. Kenya country administrator and planning workshop organizer. Email: *j.olwal@cgiar.org*

Omondi, Bonface. ARDAP. Farm liaison officer. Email: *bonomondi2007@yahoo.com*

Ongoma, Josephine. Kleen Homes and Gardens. Legume processing specialist and farm liaison officer. Email: *joseongoma@yahoo.com*

Wafullah, Teresah. MEA Fertilizers Limited. Head of BIOFIX inoculant factory. Email: *tnwafullah@gmail.com*

Waswa, Maureen. University of Nairobi. MSc student researcher (strain selection). Email: *mrnwsw@gmail.com*

Waswa, Wycliff. CIAT-Maseno. Agronomy Assistant. Email: *w.wekesa@cgiar.org*

Malawi Country Staff

Banda, Crispin. IITA-Malawi. Research Assistant. Email: *c.banda @cgiar.org*

Chataika, Barthlomew. IITA-Malawi. Research Associate and country coordinator. Email: *b.chataika@cgiar.org*

Cheyo Dominic. Department of Agricultural Extension Services (DAES). Assistant agricultural development officer. Email: *dominiccheyo@yahoo.com*

Kasongo, Gloria. IITA-Malawi. Farm liaison officer. Email: *g.kasongo@cgiar.org*

Kawalewale, Fredric. Agro-Input Supply Association. Executive Director. Email: *fredrickawalewale@ymail.com*

Kipandula, Jayaka. Department of Agricultural Extension Services (DAES). Assistant agricultural development officer. Email: *jkipandula@yahoo.com*

Khando, Sydney. Catholic Relief Services. Livelihood project manager. Email: *Sydney.Khando@crs.org*

Kumwenda, Wyclif. NASFAM. Farm services manager. Email: *wkumwenda@nasfam.org*

Lloyd, Liwimbi. Department of Agricultural Research Services (DARS). Research Scientist-Rhizobiology. Email: *sliwimbi@yahoo.com*

Mande, Kingsley. IITA-Malawi. Administrative assistant. Email: *K.Mande@cgiar.org*

Mhango, Joseph Egerton University. MSc student researcher. Email: *jmhango@hotmail.com*

Msukwa, Annily. Department of Agricultural Extension Services (DAES). Agricultural development officer. Email: *annilymsukwa@yahoo.co.uk*

Msowoya, Forward. Department of Agricultural Extension Services (DAES). Crops officer. Email: *forwardmsowoya@yahoo.com*

Mwendo, Essau. World Vision. Food Security manager. Email: *essau_mwendo@wvi.org*

Mozambique Country Staff

Colial, Henriques. Instituto de Investigação Agrária de Moçambique (IIAM), Activity Coordinator, Email: *hvcolial@gmail.com*

Daniel, Gerson. Director, Empresa Comercial dos Productores Assiociados (IKURU). Email: *gersond13@gmail.com*

Das Rosas, Nancy. IITA-Mozambique, Research Assistant. Email: *nancydasrosas@gmail.com*

Fernando, Artur. IITA-Mozambique, Farm Liaison Officer. Email: *sacambewa@yahoo.com.br*

Massimane, Adilson. IITA-Mozambique, Technician. Email: *adilsonmassimane@gmail.com*

Muananamuale, Carlos. IITA-Mozambique. Research Supervisor. Email: *charlie75np@gmail.com*

Pereira, Luis. Director of Agricultural Programs, Technoserve. Email: *lpereira@tns.org*

Rodrigues, Narciso. Technoserve. Email: *narciso.rodrigues@hotmail.com*

Rodrigues, Victor. Faculty Director, Musa Bin Bique University. Email: *pvictorrodrigues@gmail.com*

Rosario Nelito. IITA-Mozambique, Technician. Email: *neronewala@yahoo.com.br*

Salegua, Venancio. IIAM, Socio-Economist. Email: *salegua@hotmail.com*

Vidal, Maia. Team Leader, CLUSA, Angonia. Email: *maiavidal@gmail.com*

Nigeria Country Staff

Abikoye, Joseph. IITA-Kano Station. Research Supervisor/Agronomist. Email: *J.Abikoye@cgiar.org*

Abdullahi, Bala. Federal University of Technology Minna (FUT Minna). Inoculant Delivery Specialist/Technical Coordinator, Niger State. Email: *abdullahi_bala@yahoo.com*

Achina, Mercy. Data Entry Clerk. Email: *mercy_achina@yahoo.com*

Ado, A. Yusuf. Institute for Agricultural Research (IAR)-Ahmadu Bello University. Rhizobiology Studies and Agronomy Trials. Email: *adamu_99@yahoo.co.uk*

Aspeni, Gimba Stephen. Kaduna State Agricultural and Rural Development Authority (KADP). Coordinator on Delivery and Dissemination. Email: *stephenaspeni@yahoo.com*

Bukar, Kaka. IITA-Kano Station. Administrative Assistant. Email: *bukarkakathawur@ymail.com*

Chinedu, Esther. IITA-Kano Station. Farm Liaison Officer. Email: *E.chinedu@cgiar.org*

Idris, Garko Alhaji. Sasakawa Global 2000. Coordinator on Delivery and Dissemination. Email: *idrisgarko@hotmail.com*

Idris, Usman. Niger State Agricultural Mechanization and Developmental Authority. Coordinator on Delivery and Dissemination. Email: *Idris.ug66@yahoo.com*

Gambo, Isa. Sasakawa Global 2000. Coordinator on Delivery and Dissemination. Email: *gamboisa@saa-safe.org*

John, Dominic Mary. Kaduna State Agricultural and Rural Development Authority (KADP). Coordinator on Delivery and Dissemination. Email: *mjkaffoi@yahoo.com*

John, Jacob. Kaduna State Agricultural and Rural Development Authority (KADP). Coordinator on Delivery and Dissemination. Email: *dejacobdaniel@yahoo.com*

Martins, Jemo. IITA-Nigeria. Inoculant Delivery Consultant. Email: *M.Jemo@cgiar.org*

Mohammed, Jibrin. Bayero University Kano. Agronomist. *jibrin@gmail.com*

Ukem, Bassey. IITA-Kano Station. Research Associate. Email: *B.Ukem@cgiar.org*

Yola, Atiku Mohammed. Ministry for Local Government Kano State. Facilitating Partnership. Email: *atikumyola@yahoo.com*

Rwanda Country Staff

Byamushana, Cassien. Rwanda Agricultural Board (RAB). Breeder. Email: *byamushanacass@yahoo.fr*

Gatesi, Yvonne. CARITAS Rwanda. Field Supervisor. Email: *tessyvonne@gmail.com*

Hakizimana, Jacques. Developpement Rural Durable (DRD). Coordinator. Email: *jrhakizimana@gmail.com*

Kantengwa, Speciose. CIAT-Rwanda. Farm Liaison Officer. Email: *kspeciose@gmail.com*

Nsengiyumva, Aimable. Rwanda Agricultural Board (RAB). Research Assistant. Email: *bainse1@gmail.com*

Nyamwasa, Innocent. CIAT-Rwanda. Field Assistant. Email: *nycent2@yahoo.fr*

Nzeyimana, Felix. Rwanda Agricultural Board (RAB). Research Assistant. Email: *elogenzeyi@yahoo.fr*

Nzigiye, Cyrille. Conseil Consultatif des Femmes (COCOF). Agronomist. Email: *cocof_ruyumba@yahoo.fr*

Semaringa, Nzoyisenga Innocent. Eglise Presbytérienne au Rwanda (EPR). Field Coordinator. Email: *semanzoky@yahoo.fr*

Uwizerwa, Mathilde. Rwanda Agricultural Board (RAB). Rhizobiologist. Email: *uwiz99@yahoo.com*

Zimbabwe Country Staff

AGRITEX (National Extension Service). Murehwa Goromonzi, Vengesai Hwedza, Joseph Chipere Joseph, Zendera Beauty, Nyandoro Vimbai, Tawandirwa Samson, Gorogodo Matthias and Kayeruza Farisai Mudzi.

Chabata, Isaac. CIAT-Zimbabwe. Farm Liaison Officer. Email: *lipchabata@gmail.com*

Chikwari, Emmanuel. Soil Productivity Research Laboratory. Email: chikiema@yahoo.co.uk. Also Cathrine Mushangwe, Collis Mukungurutse, Akinson Tumbure, Grace Kanonge Mafaune, and Freeman Gutsa,

Dzvene, Muranganwa, Francis. CIAT-Zimbabwe. Field Technician.

Hikwa, Dansile. Principal Director, Department of Research & Specialist Services. Email: *dhikwa@africaonline.co.zw*. Also Dr Mguni and Ephraim Mabeka.

Kainga, Tatenda. University of Zimbabwe. Also Prof. S. Mpepereki, Prof. P. Mafongoya, Prof. E. Manzungu and Prof. B. Maasdorp.

Kasasa, Patrick. Community Technology Development Organisation (CTDO). Email: *patrick@ctdt.co.zw*. Also Esnath Manhiri and Stewart Mandebvu.

Kozanai, Witness. SAFIRE/CLUSA. Also Kudzai Mariga, Ben Nyakanda, Julius Sadi and Wadzanai Bopoto.

Machivenyika, Lilian. Director, Cluster Agricultural Development Services (CADS). Email: *machivenyikal@cads.org.zw*; *cadsprojects@cads.org.zw*. Also Catherine Chahweta, Shamiso Mugwara, Leonard Kuwona, Aleck Gora and Tirivavi Tatenda.

Mombeyarara, Talkmore. CIAT-Zimbabwe. Agronomist. Email: *talkmore.mombeyarara@gmail.com*

Murendo, Ephraim. Lower Guruve Development Association (LGDA). *emurendo@gmail.com*. also Janga Sekai, Sam Murira, Story Gutukunhuwa and Innocent Mangena.

Mwenye, Dorah. Agronomist AGRITEX. Email: *dorahm@mweb.co.zw*

Nyamhingura, Isabella. CIAT-Zimbabwe. Finance and Administration Officer. Email: *inyamhingura@yahoo.com*

Zamasiya, Byron. CIAT-Zimbabwe. Liaison Officer, agricultural marketing specialist. Email: *bzamasiya@gmail.com*

Annex 2. Project Milestone Reports and Publications

Note that all of these reports are or will become available through the N2Africa Project website (www.n2africa.org).

Baijukya, F. and Giller, K. E. 2012. Multi-purpose forage and tree legumes for intensive smallholder meat and dairy industries in East and Central Africa (Milestone Report 2.4.1-2). N2Africa Report No. 25 (cited in Section 4).

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Annex 3. Project Training and Extension Materials Case Studies

Many of these training materials used by N2Africa are not or only as small PDF available through the N2Africa website owing to the photograph-rich, very large size of their files or their specialized roles. These training materials may be obtained through special request to Charlotte Schilt, email: n2africa.office@wur.nl.

Technical Training

Legumes as a Business Opportunity for Agro-Input Dealers: A Trainer's tool kit- Building your Agro-Dealership with Biological Nitrogen Fixing Technology. 2014. N2Africa Project. UNIT 2: 28 pp. In press.

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A Ranking System for Legume Root Nodules. N2Africa Training Report. CIAT-Africa, Nairobi. Woomer, P.L. 2011. 2 pp.

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Agro-Dealer Training Manual Zimbabwe 2012-2013 Season. Isaac Chabata and Judith de Wolf.

Establishing a Business Plan for an Agricultural Enterprise: A Trainers Guide Manual 3. Eliud Birachi and Emily Ouma.

Training of Trainers and Lead Farmers

Biological Nitrogen Fixation and Grain Legume Enterprise: Guidelines for N2Africa Lead Farmers. Ajeigbe, H.A., Dashiell, K. and Woomer, P.L. 2010. Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture. Nairobi. 21 pp. (intended for use in Southern Africa). Also available as "*Biological Nitrogen Fixation ne Nzira dze Kutengeswa Kwe Bhinzi: Bhuku ReVatungamiriri vevarimi Muchirongwa Che N2Africa MuZimbabwe*". Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture. Nairobi. 21 pp. (translated into Shona by Isaac Chabata).

Master Farmer Training in Biological Nitrogen Fixation and Grain Legume Enterprise. Woomer, P.L. 2010.N2Africa Project, CIAT-Africa. 184 pp. Available from Paul Woomer. Also available as nine module Powerpoint presentations: Module 0 Introduction to N2Africa, Module 1 Nitrogen in small-scale agriculture, Module 2 Legumes and their uses, Module 3 Rhizobium bacteria as a biological resource, Module 4 The legume-rhizobia symbiosis, Module 5 Rhizobium inoculants, Module 6 Inoculation of legumes, Module 7 Response to legume inoculation, Module 8 Grain legume enterprise in small-scale farming, Module 9 Mobilizing communities toward BNF technologies, with accompanying practicals (cited in Section 7).

Biological Nitrogen Fixation and Grain Legume Enterprise: Guidelines for N2Africa Master Farmers. Woomer, P.L. 2010. TSBF-CIAT. Nairobi. 22 pp (cited in Section 5). Also available as "*Uambishaji Nitrojeni na Biashara ya Mazao ya Mikunde: Maelezo kwa Wakulima Wakuu Wa"* in Kiswahili (translation Chamwada, M.K) and "*Fixation de l'Azote Biologique et Entreprise de Légumineuse à Graine: Directives des Maîtres Fermiers pour N2Africa"* in French (translation by Jean-Berckmans B. Muhigwa).

An Extension Manual for N2Africa Master Farmers. A poster summarizing the Master Farmer guidelines including a list of necessary farmer skills and recommended inoculation procedures. Woomer, P.L. Powerpoint presentation.

Lead farmer guidelines for Southern Africa. A. Turner, Based upon the booklet “Biological Nitrogen Fixation and Grain Legume Enterprise: Guidelines for N2Africa Lead Farmers” by Ajeigbe, H.A., Dashiell, K. and Woomer, P.L. 2010 (also translated in Chichewa, 24 pp.).

Seed Inoculation: Master Farmer Training Practical. Woomer, P.L., 2010.

Farmer extension materials

Legume inoculation handbook. Abaidoo, R.C., Ewusi-Mensah N.E., Opoku, A. and Ahiabor, B. 2013. International Institute of Tropical Agriculture, Ibadan, 31 pp. Available from N2Africa Ghana.

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Kuweka Natrogeni Kibaologia (Swahili Nitrogen Cycle). Lekasi, J.K. 2011. This single page Powerpoint file is the first documented N cycle in Kiswahili. 385 KB.

How to Inoculate. N2Africa Training Report. N2Africa Project. no year. www.n2africa.org. (239 KB).

Best practices to maintain high yields and grain quality of soybean: A checklist prepared by the N2Africa Project for farmers in west Kenya. N2Africa Project. 2011. A single page checklist of recommended field practices for west Kenya. Also available in Kiswahili as "*Mbinu bora za kuongeza uzalishaji wa Soya, mahindi na Mtama*".

Seed Inoculation: Master Farmer Training Practical. N2Africa Training Report. CIAT-Kenya. Woomer, P.L. 2010. 6 pp. (1.2 MB).

Legume Production Notes (soya beans, sugar beans, groundnuts and cowpeas) by Isaac Chabata and Judith de Wolf (2012).

Inoculation of Legumes. Isaac Chabata (2012).

Farmers’ Handbook for Agricultural Marketing. Byron Zamasiya (2013).

Farmers’ Handbook for Agricultural Marketing: Manual for Trainers. Byron Zamasiya (2013).

Farming as a Business Guidelines. Byron Zamasiya and Isaac Chabata (2013).

Post-Harvest Handling Guidelines for Legumes. Byron Zamasiya and Isaac Chabata (2013).

Moisture Conservation in Arable Lands. Isaac Chabata (2011).

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Practical Steps to Inoculant Application – Slurry Method. Abaidoo, R.C., KNUST Kumasi. Poster.

Legume processing

Soybean Recipes for a healthy life. Abaidoo, R.C., Parwar, B., Sandoh, P., Opoku, A. and Akley, E.K. 2013. International Institute of Tropical Agriculture, Ibadan, 38 pp. Available from N2Africa Ghana

Grain Legume Processing Handbook: Value Addition to Bean, Cowpea, Groundnut and Soybean by Small-Scale African Farmers. Mulei, W.M., Ibumi, M. and Woomer, P.L. 2011. Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture. Nairobi. 42 pp.

Mwongozo wa Mafunzo ya Usindikaji wa Nafaka za Jamii Kunde: Ongezeko la Thamani kwa Maharagwe, Kunde, Karanga na Soya kwa Wakulima Wadogo Barani Afrika. Mulei, W.M. na Woomer, P.L. 2012. Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture. Nairobi. 18 pp.

Grain Legume Processing Workshop: Value Addition to Bean, Cowpea, Groundnut and Soybean by Small-Scale African Farmers. Ongoma, J. and Woomer, P. 2011. Kleen Homes and Gardens, Butere, Kenya 16 to 18 March 2011. A Powerpoint presentation in five sections: Module 1 Introduction to Legume Processing, Module 2 Legumes and Human Nutrition, Module 3 Post-harvest Handling, Module 4 Household Diets and Recipes, Module 5 Organizing a Cooking Contest. Includes other supporting training materials. N2Africa Training Office, CIAT-Africa. Also available in Kiswahili.

Mince and Press Soymilk. Ongama, J. and Woomer, P.L. 2012. A poster describing a five-step preparation method for soymilk, including costs and returns. Powerpoint presentation.

Mwongozo wa Mafunzo ya Usindikaji wa Nafaka za Jamii Kunde: Ongezeko la Thamani kwa Maharagwe, kunde , Karanga na Soya kwa Wakulima Wadogo Barani Afrika. Grain legume processing presentation in Kiswahili. Ongoma J. and Woomer P. L., N2Africa training office, 2011. 50 pp.

Annex 4. Project video and media platforms

From its outset, the N2Africa Project documented its operations through video productions produced by Taskscape Associates Ltd. Cumbria UK with the assistance of The University of Cumbria and led by Alastair Simmons. The purpose was to facilitate the communication of ideas, activities, knowledge capture and exchange.

Eighty videos were made of:

- Tools and techniques
- Technologies and methods
- Interviews of outcomes and lessons learned
- Particular crops and countries
- Training (and to train) farmers, project and extension workers
- Some user and in-country generated content.

Figure 11.1: The map directory of N2Africa videos appearing in www.n2africa.tv website

Videos can be accessed via the N2AfricaTV Portfolio on the project website (http://www.n2africa.tv). or through an interactive map directory where videos were linked to location, intervention, activity data and photographs. (Figure 11.1). Integration of media was important as the project narrative developed and assisted with incorporation of video-led content across Facebook and Podcasters. The Vimeo platform gave viewer analytics and the videos have provided a record of success.

A selection of 23 videos organized by country follows.

DR Congo

- Introduction to N2Africa (DR Congo): People and Places. A round-up illustrating the diversity of people and places involved in the N2Africa project in DR Congo. Length 2 minutes.
- Development of the Kalambo Research Centre (2009-2013). The construction and operations of a new IITA agricultural research centre in South Kivu. Length 7 minutes.
- Interdisciplinary collaboration and public goods. Describes collaboration between development economists and the N2Africa project in South Kivu, the understanding of technology dissemination and how knowledge is shared among rural communities. Length 12 minutes.

Ghana

- Introduction to N2Africa (Ghana): People and Places. A round-up illustrating the diversity of people and places involved in the N2Africa project in Ghana. Length 2 minutes.
- Nutritional Benefit of Grain Legume Cultivation in Northern Ghana. Describes a case study examing the nutritional benefits accrued through farmer participation in the project. Length 23 minutes.
- Farmers' views from Ghana. A conversation with Zenabu Abdulai, Sadia Fusheni and Munira Alhassen, Lead Farmers assisting in technology dissemination in Ghana. Length 3 minutes.

Kenya

- Introduction to N2Africa (Kenya): People and Places. A round-up illustrating the diversity of people and places involved in the N2Africa project in west Kenya. Length 2 minutes.
- N2Africa Farmer Irene Ngochi. A conversation with Irene Ngochi, a Master Farmer in west Kenya growing soybeans and climbing beans. Length 5 minutes.
- Policy Support for Inoculant and Legume Technologies: Describes policy support for legume inoculant technologies based upon a conversation with Prof. Nancy K. Karanja, Director of the Microbial Resources Centre, University of Nairobi. Length 4 minutes.

Malawi

- Introduction to N2Africa (Malawi): People and Places. A round-up illustrating the diversity of people and places involved in the N2Africa project in Malawi. Length 2 minutes.

Mozambique

- Introduction to N2Africa (Mozambique): People and Places. A round-up illustrating the diversity of people and places involved in the N2Africa project in Mozambique. Length 2 minutes.
- Smallholder farmers and commercial opportunity. Country Coordinator, Steve Boahen, discusses with a farmer and the Project Coordinator, Jeroen Huising, the use of land by smallholder farmers conducting commercial enterprise. Length 7 minutes.
- Dissemination partnership in Mozambique. A conversation with Gerson Daniel, General Manager of IKURU and its production and marketing operations. Length 4 minutes.
- N2Africa strategy and operations in Mozambique. An interview with Dr Steve Boahen, Country Coordinator in Mozambique. Length 5 minutes.

Figure 11.2: Taskscape film crew in action in Mozambique

The Netherlands

- Introduction to N2Africa (Wageningen University): People and Places. A round-up illustrating the diversity of people and places involved in the N2Africa project at Wageningen University in The Netherlands. Length 2 minutes.

Nigeria

- Introduction to N2Africa (Nigeria): People and Places. A round-up illustrating the diversity of people and places involved in the N2Africa project in Nigeria Length 2 minutes.

Rwanda

- Introduction to N2Africa (Rwanda): People and Places. A round-up illustrating the diversity of people and places involved in the N2Africa project in Rwanda. Length 2 minutes.
- COCOF, a women farmer group in Rwanda. Speciose Kantengwa, BNF technology dissemination leader in Rwanda, introduces the operations of a women's group.

- Adoption and adaption of legume technology in Rwanda. Dr Freddy Baijukya, Legume Agronomy Leader, introduces the ways that farmers in Rwanda have adopted and adapted their field practices following the introduction of nitrogen fixation legume technology. Length 2 minutes.

Zimbabwe

- Seed quality and variety preference. N2Africa team members in Zimbabwe reflect on seed quality and variety preferences. Length 8 minutes.
- Value chain and markets. N2Africa team members in Zimbabwe reflect on grain legume value chains and expanding market opportunities for small-scale farmers. Length 3 minutes.
- Legume agronomy. N2Africa team members in Zimbabwe reflect on legume agronomy experiments and how these relate to identifying useful technologies for small-scale farmers. Length 2 minutes.
- Farmer groups and agricultural cooperatives. N2Africa team members in Zimbabwe reflect on farmer groups and agricultural cooperatives, and their services offered to members. Length 2 minutes.

Annex 5. Project Graduate Students

MSc students

The N2Africa Project supported MSc students expected to research topics directly related to project tasks in legume agronomy, rhizobiology and technology adoption. Most of these MSc students studied at home-country public universities, but in some cases (DR Congo and Mozambique) they were hosted by other countries.

Table 11.1: MSc students whose tuition, stipend and work was directly supported by N2Africa.

Name	date	Title	University	Supervisors
Abdul-Aziz Abdul-Latif.	September 2013	Contribution of Rhizobium inoculant and phosphorus fertilizer application to biological Nitrogen fixation and grain yield of soybean in Tolon District	Kwame Nkrumah University of Science and Technology (Ghana)	Dr Andrews Opoku
Abubakar, Fatima Jibrin.	2014*	Isolation, identification and characterization of rhizobia nodulating promiscuous soybean genotype in the savannas of Nigeria	Ahmadu Bello University.	Dr Ado Yusuf and Dr Abdullahi Bala
Balume, Isaac Kayani	October 2013	Assessment of quality control of inoculants on bean and soybean in Eastern and Central Africa	University of Nairobi (Kenya)	Prof. S. Keya
Aliyi Abdulah, Ibsa	June 2013	Agronomic and symbiotic characteristics of chickpea, *Cicer arietinum* (L.), as influenced by Rhizobium inoculation and phosphorus fertilization under farming systems of Wolaita area, Ethiopia	Wageningen University	Dr Katrien Descheemaeker, Prof. Ken Giller and Dr Endalkachew Wolde-meskel
Badza, Taruvinga	2014*	Nutritional and soil fertility benefits: influence of fertilizers on groundnuts (*Arachis hypogaea* L.) yield and soil nitrogen contribution for smallholder farmers in Uganda.	Wageningen University	Prof. Ken Giller, Dr Linus Franke and Dr Peter Ebanyat
Balangaliza Barhebwa, Fidèle	2014*	Competitiveness of Legume Production in Small Scale Farming in South Kivu, Eastern Democratic Republic of Congo	Kenyatta University (Kenya)	DR Eric Bett and Prof. Bernard Njehia
Bressers, Elise	2014*	Nutrient deficiencies and soil fertility constraints for common bean (*Phaseolus vulgaris* L.) production in the Usambara Mountains,	Wageningen University	Dr Linus Franke, Dr Freddy Baijukya and Prof. Ken Giller.

		northern Tanzania		
Breure, Mirjam and Kool, Hanna	February 2014	Farmers' practices and value chain of climbing bean production in South Western Uganda (Internship report)	Wageningen University	Dr Peter Ebanyat and Esther Ronner
Chipomho, Caroline	January 2013	MSc Internship Report on work done in Zimbabwe	Wageningen University	Judith de Wolf and Prof. Ken Giller
Collombet, Robin	June 2013	Investigating soyabean market situation in Western Kenya: constraints and opportunities for smallholder producers (MSc minor thesis)	Wageningen University	Dr Freddy Baijukya and Esther Ronner
Dunjana, Sibonginkosi	2014*	A socio-economic analysis of the determinants of legume production among smallholder farmers in Zimbabwe	University of Zimbabwe	Prof. PL Mafongoya and Dr J Mtambara
Foli, Samson	June 2012	Farm characterisations in the southern and northern Guinea savannah zones of Nigeria	Wageningen University	Dr Linus Franke and Prof. Ken Giller
Foli, Samson	July 2012	Qualitative and quantitative diagnosis of macro and micronutrient deficiencies in soils across three agro-ecological environments of northern Nigeria using the double-pot technique (Internship report)	Wageningen University	Dr Linus Franke and Prof. Ken Giller
Kainga, Tatenda.	2014*	Symbiotic effectiveness of indigenous rhizobial isolates and effect on smallholder soyabean productivity in Zimbabwe	University of Zimbabwe	Prof. S Mpepereki and Prof. PL Mafongoya
Ludy, Keino	2014*	Nutrients limiting soybean (*Glycine max* L.) production in the degraded soils of Busia and Kakamega counties	University of Eldoret, Kenya	Dr Freddy Baijukya
Khonje, Kondwani	July 2011	Farmer's trial legume technology evaluation in the districts of Mchinji and Salima in Central Malawi (Internship report)	Wageningen University	Dr Linus Franke
Klapwijk, Lotte	April 2011	Availability of animal feed resources at farm and village scale in Umurera, Rwanda	Wageningen University	Dr Mark van Wijk, Prof. Ken Giller and Prof. Frans Bongers

Klapwijk, Lotte	August 2011	A comparison of the use of bean stakes in northern Rwanda (Internship report)	Wageningen University	Dr Linus Franke and Prof. Ken Giller
Langwerden, Jori	2014*	Soil fertility constraints of the production of common bean (*Phaseolus vulgaris*) in the Usambara Mountains of northern Tanzania	Wageningen University	Dr Linus Franke, Dr Freddy Baijukya and Prof. Ken Giller
Manenji, Brenda, T.	October 2011	Understanding the current role of legumes and their significance for Biological Nitrogen Fixation (BNF) in smallholder farming systems of Zimbabwe	Wageningen University	Prof. Ken Giller and Dr Linus Franke
Mhango, Joseph	2014*	Evaluation of the efficacy and competitiveness of indigenous rhizobia on soybean (*Glycine max* (l.) Merr.). Nodulation, nitrogen fixation and growth	Egerton University	Dr Nancy Mungai and Dr Patson Nalivata,
Mucavêa Mônea Lina Adelino	2014*	Determining nutrients limiting factors on grain yield and yield components to common beans (*Phaseolus vulgaris* L.) under drought and non-drought conditions	University of Malawi- Bunda college/LUANAR	V. Kabambe PhD, W. Muhango PhD, Rowland PhD
Mujawamariya, Myriam	July 2012	Identification of Potential Niches for Soybean cultivation in Farming systems of Eastern and Southern Rwanda	Wageningen University	Prof. Ken Giller and Dr Linus Franke
Mukankubana, Domitille	2014	Evaluation of bean technologies dissemination in Rwanda: the case of improved bean varieties	National University of Rwanda	Judith de Wolf
Mutuma Patrick, Samuel	December 2013	Farmer perceptions, use and profitability of Biofix® on soyabean (*Glycine Max*) production in Western Kenya	University of Nairobi	Dr Julius Okello, Prof. Nancy Karanja and Paul Woomer PhD
Ndusha, Bintu Nabintu	2014*	Inventory and characterisation of rhizobia in East Congo and assessment of their capacity to nodulate with soybean	University of Nairobi (Kenya)	Prof. Nancy Karanja
Nyirenda Esnart	2014*	Assessment of the diversity of cowpea rhizobia in soils from different cropping systems in Chiwosya Extension Planning Area.	University of Malawi- Bunda College/LUANAR	Dr Patson Nalivata, Dr Kingdom Kwapata, Dr Julie Grossman

		Mchinji district		
Omondi, John Okoth	May 2013	Tillage and variety effects on soil moisture content, biological nitrogen fixation and soybean (G*lycine max* l. merril) yield in western Kenya	Egerton University	Dr Nancy Mungai
Parachini, Elie	April 2012	Rapport d'activites du stage au Malawi (Internship report)	Université de KwaZulu Natal	Dr Anne Turner
Paut, Raphael	June 2013	Potentials and challenges of climbing bean production in Western Kenya. Some background (theory and case studies) on technology adoption and adaptation by smallholder farmers (MSc minor thesis)	Wageningen University	Dr Freddy Baijukya and Esther Ronner
Reckling, Moritz	Januari 2011	The Rwandan Household Typology 'Ubudehe' (Internship report)	Wageningen University	Dr Bernard Vanlauwe, Prof. Ken Giller and Dr Linus Franke
Reckling, Moritz	August 2011	Characterisation of Bean Farming Systems Across Farm Types in Northern and Eastern Rwanda, Identification of Potential Niches for Legume Technologies	Wageningen University	Linus Franke and Ken Giller
Rumonge, Alfred Tabaro	2013	Evaluation of effectiveness of rhizobia isolates from rwandan soils on common bean (*Phaseolus vulgaris*)	University of Nairobi (Kenya)	Prof. Shellemiah Keya, Prof. Nancy Karanja, Paul Woomer PhD
Siyeni, Donald	2014*	Effect of rhizobia inoculation and phosphorus fertilizer application on nodulation and yield of soybean in Dedza, Salima and Kasungu districts of Malawi	University of Malawi- Bunda College/LUANAR	Dr Wezzie. Mhango, Dr V. Kabambe, Dr M. Lowole
Ulzen, Jacob	September 2013	Assessing the need for inoculation of soybean and cowpea at Tono in Kassena Nankana District of the Upper East Region of Ghana	Kwame Nkrumah University of Science and Technology, Ghana	Dr Nana Ewusi Mensah
Van 't Foort, Jelte, Mgasa, Doto, Zagenia, Felicity and Manyere, Fadzai	2014*	Non-facilitated diffusion of N2Africa technologies in Kenya, Malawi, Ghana and Zimbabwe	Wageningen University	Dr Conny Almekinders, Dr Freddy Baijukya, Dr Barthlomew Chataika, Dr

				Benjamin Ahiabor, Judith de Wolf
Van den Brand, Greta	August 2011	Towards increased adoption of grain legumes among Malawian farmers – Exploring opportunities and constraints through detailed farm characterization	Wageningen University	Dr Linus Franke and Prof. Ken Giller
Van der Bom, Frederik	November 2012	Response of *Phaseolus vulgaris* L. and *Pisum sativum* L. to N and P fertilizers and inoculation with Rhizobium in Kenya	Wageningen University	Prof. Ken Giller and Dr Linus Franke
Van der Bom, Frederik	May 2013	Soya ni pesa (Internship report)	Wageningen University	Prof. Ken Giller and Dr Linus Franke
Van der Starre, Wietske	October 2012	Nutrient limitations for soybean on low-responsive sandy soils in Zimbabwe tested by a double pot experiment	Wageningen University	Dr Linus Franke
Vida, Peter	2014*	Research topic addressing socio-economics	Bayero University Kano	Dr Aminu Suleiman
Waswa, Maureen	2013	Identifying elite rhizobia for commercial soybean (*Glycine max*) inoculants	University of Nairobi	Prof. Nancy Karanja
Wekesa, Anne (self-supporting)	2014*	Isolation, identification, characterization and quality control of rhizobia using molecular techniques	University of Nairobi	Prof. Ochanda

* Not graduated at moment of publishing this report, final title not confirmed

Annex 6. Project Case Studies

A series of case studies were commissioned by N2Africa on a wide range of topics. Of particular interest were in-depth studies on adoption of BNF technologies and how they are tailored to local conditions. Program cooperators were invited to submit case study topics that were evaluated by a selection team at Wageningen University in consultation with Country Coordinators. A description of the overall impacts of these case studies appears in Section 3 of this report. Summaries of these case studies follow, many of which are available through the project website http://www.n2africa.org/all_msc_reports.

Case Studies addressing production systems

Seed systems and sources of inputs in Mozambique.

N2Africa Country Team. A survey was conducted to assess factors at household level that may have determined success or failure of continued use of improved legume varieties. The survey revealed that farmers sourced cowpea, groundnut and soyabean seed from IITA, government organizations, NGOs, private companies and from other farmers. Constraint in access to improved varieties included lack of credit facilities, lack of physical and timely availability of seed and high prices. Different approaches relying upon Lead Farmers were devised to disseminate improved legume varieties (Table 11.2) in Mozambique.

Table 11.2: Strategies employed to disseminate improved legume varieties in Mozambique.

strategy	limited	intermediate	intensive
lead farmers mobilized	+	+	+
compact demonstrations	0	+	+
larger demonstrations	0	0	+
seed distribution	+	+	+
fertilizer distribution	+	0	0
farmer training	0	+	+
credit offered for seed	0	+	+
agrodealer training	0	+	+

Potential and challenges of climbing bean production in Western Kenya.

Raphaël Paut, Wageningen University. Two varieties of climbing beans (Kenya Tamu and RWV 13148) were grown in rotation systems on a very small area (0.057 ha) with manure (77% of farmers) and fertilizer (55% of farmers, of which 50% used DAP and 42% Sympal). Farmers supported climbing bean using individual stakes, tripods, intercropping with maize, strings and living trees. Farmers were positive about productivity, taste, capacity for BNF and soil fertility improvement. Climbing beans required less land and was easier to harvest compared to bush bean. The major constraints to climbing bean adoption in Western Kenya follow in this order; extensive labor needs, lack of crop knowledge, lack of staking materials, lack of seed and bird attack.

Case Studies addressing technology adoption

Adoption and adaptation of BNF technologies in DR Congo.

N2Africa Country Team. A survey was conducted among seven farmer groups through focus group discussions and individual interviews. In terms of BNF technology, 12% of the farmers trained on crop management adopted intercropping, 14% used inoculants on soyabean, 66% used improved seeds and fertilizers, majority farmers (76%) were trained on the 6th pack with rhizobia, more than half (54%) changed the protocol in search of better harvest and some farmers for the sake of habit and food needs while 36% of farmers experienced an improved livelihood and nutrition. A good level of knowledge and appreciation of BNF technology by farmers, and comparative advantage was realized: 45% of farmers realized an increase in yields and 31 % appreciate the use of fertilizer.

Factors influencing soyabean production and willingness to pay for inoculant in northern Ghana.

R. Aidoo and others. This study examines the key factors that drive soyabean production in northern Ghana, and evaluates the principal factors that determine farmers' willingness to pay for the soyabean inoculant. Results indicate that more farmers (80%) are willing to pay for inoculant if it were available than are actually aware of inoculation as a practice (60%), a counterintuitive finding. Awareness creation about inoculant and improved access to credit will significantly enhance uptake by farmers, and more commercially oriented soyabean producers should be targeted first in any attempt to introduce commercial inoculant. More information is available from the paper by Aidoo R., Mensah J.O., Opoku A., Abaidoo R.C. 2013. Factors influencing soyabean production and willingness to pay for inoculum use in northern Ghana, *American Journal of Experimental Agriculture* (in press).

How farmers acquire and share N2 Africa knowledge and technologies in Kenya, Malawi, Ghana and Zimbabwe.

Esther Ronner and the N2Africa Team. In each country, two villages where N2Africa worked were chosen and within each village these factors studied: "Snowballing" from lead/satellite farmers outwards (in relation to seed, information/knowledge and technology), and sampling the source/targeted and neighboring villages. Farmers share small quantities of seed and information with neighbours and relatives, sometimes at large distances. Information sharing was most common among men and seed sharing among women, usually as gifts to relatives. Unfortunately, farmers do not use inoculants or legume fertilizers when they are not in ready commercial supply or under competing needs for limited cash.

Farmer adaptation of technologies in Ghana, Malawi, Rwanda, DR Congo and Zimbabwe.

Esther Ronner and the N2Africa Team. An inventory of farmers' adaptations of N2Africa technologies conducted in four countries. Farm Liaison Officers and dissemination partners reported on the type of adaptations observed in the field, the reasons why farmers deviated from the demonstrated technology and the advantages and disadvantages of the adaptation. The most common adaptations were a change from monocropping of legumes in N2Africa demonstrations to intercropping with cereals legumes and increased plant density. Other adaptations were the application of NPK fertilizer on cereals instead of P-fertilizer on legumes; broadcasting of legumes instead of row planting; mixing of improved and local legume varieties, delays in planting time to reduce pest pressure and mulching of legumes. Adaptations were often applied to reduce the workload and to maximize the use of limited land, but sometimes came at the cost of reduced yields. Interaction with farmer adoptation allows for N2Africa technologies to be rapidly adjusted to specific agro-ecologies and cropping systems.

Activities of a model Lead Farmer in Malawi.

Crispin Emmanuel. This study provides a detailed portrait of a successful Lead Farmer in Malawi. It suggests that that higher education, past training experience, and higher socioeconomic status contribute to effective performance by a Lead Farmer.

Evaluating the effectiveness of Lead Farmers in Zimbabwe.

N2Africa Zimbabwe Country Team. This study documents the views and perceptions of both Lead and follower farmers on how the former provided training after he/she had received it. Data analysis identifies major socio-economic factors that contribute to grassroots training and assess knowledge gained by follower farmers before and after training. It concludes with a qualitative assessment and recommendations on the selection of effective Lead Farmers in the future, and the strengths and weaknesses of the lead farmer approach as an alternative grassroots extension approach.

Case Studies addressing marketing

Performance of the grain legume marketing systems in Northern Ghana.

R. Aidoo and others. This study examines the costs, returns and efficiency levels associated with the activities of key players along the grain legume marketing chain in northern Ghana. It relies upon surveys and interviews with participants from major and satellite markets in northern Ghana. Assessment of different grain legume pathways from farm gate to final consumer showed that there are more than four different channels through which soyabean, cowpea and groundnut are distributed and traded. Wholesaling and retailing of these grain legumes in northern Ghana is profitable, but margins are not equitably distributed along the marketing chain. Trading in groundnut was far more profitable than trading in cowpea or soyabean. The main constraints identified by grain legume traders were limited access to credit, high cost of transportation, poor road networks and inadequate storage facilities. More information on this study is available from Aidoo R., Mensah J.O., Opoku A., Abaidoo R.C. (2013). Assessing the performance of the grain legume marketing system in northern Ghana, *International Journal of AgriScience*, Vol. 3 (10): 787-795.

The soyabean market situation in Western Kenya: constraints and opportunities for smallholder producers.

Robin Collombet, Wageningen University. The goal of this study was to assess the current situation of soyabean production and markets by analysing existing constraints and opportunities for both factors. Interviews were conducted with relevant actors along the soyabean value chain. Results indicated that net profit from soyabean production was on average $85 per year with high variability among farmers. Farmers with high yields were generally enthusiastic about soyabean production and constitute a great potential to stimulate soyabean production in the region. In addition, members of Soyabean Resource Centers initiated under the Tropical Legumes II project should receive further training to increase their entrepreneurship skills and to develop into autonomous cooperatives for production and marketing of soyabean. Further soyabean marketing opportunities should be explored at schools, small shops and eventually larger scale processors.

Case Study addressing nutrition

Nutritional benefits of grain legume cultivation in Northern Ghana and in Western Kenya.

Ilse de Jager and Esther Ronner, Wageningen University. A comparative study in northern Ghana and western Kenya was conducted to assess the effect of improved agricultural productivity on the nutrient

Table 11.3: Individual Dietary Diversity Score (IDDS) and nutritional status indicators of children 6-59 months of age from N2Africa participants and from non-N2Africa participants.

Outcomes	Unit	Non-N2Africa villages	N2Africa villages
IDDS, out of 14 food groups	Mean (SD)	5.1 (1.8)	5.5 (1.9)*
for children 2 to 5 years	Mean (SD)	5.6 (1.3)	6.1 (1.2)*
Consumption of legumes, nuts and seeds	% (N)	77.	87**
for children 2 to 5 years	% (N)	86	95**
Wasting, (%)	% (N)	11	6

*P<0.05 (Mann-Whitney U test); **P<0.05 (Chi-square test) adequacy of the diet and nutritional status of children under 5 years of age, and to explore the potential pathways through which improved legume productivity may affect nutrition security of the household. In Ghana, children (between 2 and 5 years old) of N2Africa participants had a more nutrient adequate diet compared with non-N2Africa participants and consume more ‘legumes, nuts and seeds’, but there was no difference in nutritional status (Table 11.3). Female N2Africa participants and N2Africa participants who received training on soyabean preparation mostly used the legume yield for home consumption; male N2Africa participants mostly used the yield for sales. It is unclear if (and how) improved sales lead to enhanced nutritional status. The effect of N2Africa activities on nutrition could be improved through targeting female farmers and providing trainings on soyabean preparation methods. Results from the case study in Western Kenya are expected in January 2014. A short film on this case study in Ghana is available at: http://www.n2africa.tv/.

Annex 7. Gender disaggregation of project beneficiaries

The project target was to achieve at least 50% female participation in project activities. Information on gender and the balance between male and female project participants was collected through the M&E framework. However, field activities had already started before the M&E framework was fully developed (discussed in 'lessons learned'). Therefore the gender disaggregation is not entirely complete for all countries and project years. … In the following section, the gender disaggregation among project beneficiaries is discussed per country.

Ghana: Fewer women than men participate in full-time farming activities (46% versus 62%). Yet, women's seasonal involvement is generally larger than that of men (women 42% vs. men 30%). Data on input distribution is not available for 2010 and only very limited for 2011. From the limited 2011 data, we saw that about 40% of beneficiaries were female. Differences between regions were large, from 14% to 67% female beneficiaries. In 2012, almost 42% of the participants in N2Africa who received inputs were women. Throughout the four years, the percentage of female Lead Farmers was rather stable with 30 to 33%. Participants of field days were female in 47% and 48% of cases in 2011 and 2012 respectively (incomplete data). For 2012 we know that women participation in field days ranged from 20% to 66%, depending on area. Extension staff in Ghana is male dominated and few female extension workers participated in trainings. Amongst the farmers trained, 15 to 37% were women.

Nigeria: The M&E data reflect that in large parts of Northern Nigeria, women are less engaged than men in agricultural activities in the fields. For example, in 2011, in Kano only 4% of Lead Farmers were women, in Kaduna 11%. In 2012, women receiving inputs from N2Africa varied from 12% to almost 22%, depending on area. The average percentage of women Lead Farmers in 2012 is just over 13%. N2Africa developed specific training activities for women, particularly in the area of legume processing.

DR Congo: Women are more involved in agricultural activities in the eastern region of DR Congo than men. This is also reflected in the participation in the N2Africa project. In the early years, on average, 50% of training participants were female. During exchange visits more than 62% of the participants were female. In Field days, the female participation was even over 71%. Overall this trend continued and in some cases the female participation increased even further. One of the partner organizations in DR Congo is a women organization, mainly targeting female farmers. This is part of the reason why women participation was very high in DRC. Yet, women participation was also high new satellite sites with different development partners.

Rwanda: Overall participation in agriculture in Rwanda is quite equal between men and women; however, the participation of women in N2Africa activities has always been high and even increased over time. In 2011A and 2011B over 62% of the participants were female (varying from 55% to over 76% in the different impact zones). Towards the end, the average percentage of female participants was over 67%. Two of the N2Africa partners made special efforts to conduct trainings aimed at empowering women, such as land rights and household power relations. This pro-active engagement can provide useful lessons for Phase II for addressing gender inequalities.

Kenya: Because the Kenya country team was dependent on organizations sending participants, they did not achieve 50% women participation in all training events. However, the target of 50% women participation was largely met in other aspects. In early stages of N2Africa, 44% of the trained Master Farmers were female, half of the node leaders were female and 84% of the participants in a grain legume-processing workshop were female. Input distribution has reached women well: in 2010 LR and SR, almost 62% of the farmers reached were female, 2011 SR 56% of recipients were female – the variance between the different nodes was not great (49% to almost 62%). However, with 37%, the percentage of female Master Farmers was lower in this season. The information on training is not complete. For field days, as far as it is recorded, the overall participation of women was around 50%.

Malawi: In the first season, 51% of the participating farmers were female, and 49% of the Lead Farmers were female. For the 2011-12 season, 48% of the recipients of inputs were female, 51% of field day participants were female and in the nutrition and processing training, 68% of the participants were female. There have been some specific activities targeting women in Malawi, such as nutrition and legume processing. For the 2012-13 season, no data was available.

Mozambique: M&E data available from Mozambique is very limited and therefore it is difficult to give a reliable impression of women's participation in N2Africa activities. For the 2010-11 season, it was reported that 17% of the farmers reached were female. From the farmers reached in 2011-12, over 33% were female (for soybean 28%, for groundnut 63%) (from country report, no complete M&E records available). From the Lead Farmers trained in 2011-12, 44% were female. From the demonstrations established, 29% were established on fields of female farmers. Training on home utilization of soybean for improved protein and energy consumption targeted women and achieved 65% female participation (July-Sept 2012). Records for field days are incomplete, but female participation is somewhat low, around 29%. All in all it seems that although there was increased participation of women over the years and the N2Africa baseline found that more than 80% of the women indicated to be full-time involved in farming, the 50% target was not reached.

Zimbabwe: On average, the percentage of female farmers receiving inputs from N2Africa has been consistently high at 62% to 65%. In the first season 2010-11, over 51% of the Lead Farmers were female. The average percentage of female Lead Farmers in 2011-12 was almost 47%. However, there was variation among different districts. In 2011-2012 the percentage of female farmers receiving inputs ranged from 48% to more than 74%. The percentage of female Lead Farmers varied between 28% and 64%. These variances provided lessons for all partners to learn from one another on how to ensure participation of female farmers in all activities. Over the years average training participation has been above 50%, to even 58% in 2012-13 season. Field days were generally well attended by women, generally above 60% was female. Only in the specific training for agro-dealers, there was a 30% participation of women. In all years, one partner organisation made specific efforts to reach women through trainings on processing and nutrition that had usually almost 100% female participation.

List of project reports

1. N2Africa Steering Committee Terms of Reference
2. Policy on advanced training grants
3. Rhizobia Strain Isolation and Characterisation Protocol
4. Detailed country-by-country access plan for P and other agro-minerals
5. Workshop Report: Training of Master Trainers on Legume and Inoculant Technologies (Kisumu Hotel, Kisumu, Kenya-24-28 May 2010)
6. Plans for interaction with the Tropical Legumes II project (TLII) and for seed increase on a country-by-country basis
7. Implementation Plan for collaboration between N2Africa and the Soil Health and Market Access Programs of the Alliance for a Green Revolution in Africa (AGRA) plan
8. General approaches and country specific dissemination plans
9. Selected soyabeans, common beans, cowpeas and groundnuts varieties with proven high BNF potential and sufficient seed availability in target impact zones of N2Africa Project
10. Project launch and workshop report
11. Advancing technical skills in rhizobiology: training report
12. Characterisation of the impact zones and mandate areas in the N2Africa project
13. Production and use of Rhizobial inoculants in Africa
18. Adaptive research in N2Africa impact zones: Principles, guidelines and implemented research campaigns
19. Quality assurance (QA) protocols based on African capacities and international existing standards developed
20. Collection and maintenance of elite rhizobial strains
21. MSc and PhD status report
22. Production of seed for local distribution by farming communities engaged in the project
23. A report documenting the involvement of women in at least 50% of all farmer-related activities
24. Participatory development of indicators for monitoring and evaluating progress with project activities and their impact
25. Suitable multi-purpose forage and tree legumes for intensive smallholder meat and dairy industries in East and Central Africa N2Africa mandate areas
26. A revised manual for rhizobium methods and standard protocols available on the project website
27. Update on Inoculant production by cooperating laboratories
28. Legume Seed Acquired for Dissemination in the Project Impact Zones
29. Advanced technical skills in rhizobiology: East and Central African, West African and South African Hub
30. Memoranda of Understanding are formalized with key partners along the legume value chains in the impact zones
31. Existing rhizobiology laboratories upgraded
32. N2Africa Baseline report
33. N2Africa Annual country reports 2011

34. Facilitating large-scale dissemination of Biological Nitrogen Fixation
35. Dissemination tools produced
36. Linking legume farmers to markets
37. The role of AGRA and other partners in the project defined and co-funding/financing options for scale-up of inoculum (banks, AGRA, industry) identified
38. Progress Towards Achieving the Vision of Success of N2Africa
39. Quantifying the impact of the N2Africa project on Biological Nitrogen Fixation
40. Training agro-dealers in accessing, managing and distributing information on inoculant use
41. Opportunities for N2Africa in Ethiopia
42. N2Africa Project Progress Report Month 30
43. Review & Planning meeting Zimbabwe
44. Howard G. Buffett Foundation – N2Africa June 2012 Interim Report
45. Number of Extension Events Organized per Season per Country
46. N2Africa narrative reports Month 30
47. Background information on agronomy, farming systems and ongoing projects on grain legumes in Uganda
48. Opportunities for N2Africa in Tanzania
49. Background information on agronomy, farming systems and ongoing projects on grain legumes in Ethiopia
50. Special Events on the Role of Legumes in Household Nutrition and Value-Added Processing
51. Value chain analyses of grain legumes in N2Africa: Kenya, Rwanda, eastern DRC, Ghana, Nigeria, Mozambique, Malawi and Zimbabwe
52. Background information on agronomy, farming systems and ongoing projects on grain legumes in Tanzania
53. Nutritional benefits of legume consumption at household level in rural sub-Saharan Africa: Literature study
54. N2Africa Project Progress Report Month 42
55. Market Analysis of Inoculant Production and Use
56. Grain legumes and fodder legume materials with high Biological Nitrogen Fixation Potential identified in N2Africa impact zones
57. A N2Africa universal logo representing inoculant quality assurance
58. M&E Workstream report
59. Improving legume inoculants and developing strategic alliances for their advancement
60. Rhizobium collection, testing and the identification of candidate elite strains
61. Evaluation of the progress made towards achieving the Vision of Success in N2Africa
62. Policy recommendation related to inoculant regulation and cross border trade
63. Satellite sites and activities in the impact zones of the N2Africa project
64. Linking communities to legume processing initiatives
65. Special events on the role of legumes in household nutrition and value-added processing
66. Media Events in the N2Africa project

67. Launch N2Africa Phase II – Report Uganda
68. Review of conditioning factors and constraints to legume adoption and their management in Phase II of N2Africa
69. Report on the milestones in the Supplementary N2Africa grant
70. N2Africa Phase II Launch in Tanzania
71. N2Africa Phase II 6 months report
72. Involvement of women in at least 50% of all farmer related activities
73. N2Africa Final Report of the First Phase: 2009-2013

Partners involved in the N2Africa project

A2N

Bayero University Kano (BUK)

Caritas Rwanda

Diobass

Eglise Presbyterienne Rwanda

Kwame Nkrumah University of science and Technology

Resource Projects-Kenya

SARI

Sasakawa Global; 2000

Université Catholique de Bukavu

MIRCEN
University of Nairobi MIRCEN

University of Zimbabwe

Urbanet