N2Africa uses a step-wise approach to deployment of legume and inoculants technologies with strong BNF capacity, focusing initially on “quick wins” - employing existing proven technologies based on success feedback from researchers, farmers, extensionists and other partners.

**Effecting change at farm level**

- Package proven technologies with available inputs
- Work through established grassroots groups (positive peer pressure, collective action)
- Develop diagnostic skills through extension campaigns, field demonstration and farmer field days

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**A PARTNERSHIP APPROACH**

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Soil samples from different agro ecological zones are collected and assessed for their rhizobial populations as well as "need to inoculate" in order for nitrogen fixation to occur.

Several rhizobiology laboratories have been renovated and new equipment purchased to enable them to conduct quality analyses. Several NARS staff as well as N2Africa Research Officers have undergone training in rhizobiology so as to gain new skills and expertise.

Several M.Sc. and PhD students sponsored by N2Africa are pursuing rhizobiology topics at respective levels.

The life cycle of rhizobia consists of three phases, each with their own milestone events and constraints to achieving effective symbiotic nitrogen fixation.

The saprophytic phase of the cycle, rhizobia may persist in the absence of the legume hosts either in the bulk soil, the decaying root nodules from previous symbiosis, or in the rhizospheres of non-host plants.

The infective phase in the cycle of rhizobia represent a series of events involving both symbiotic partners. The infection process is sensitive to stresses of the environment, particularly soil acidity and salinity.

The symbiotic phase of the cycle refers to the development and function of root nodules. This phase is also subject to environmental factors that affect the host plant.

High numbers of native rhizobia present a competitive barrier to the successful establishment of introduced rhizobia.

Effectiveness testing of isolates from Kenya has identified several candidate elite strains for field testing.

Parameters included on the Kenyan Rhizobium Isolate Database

Source country: NA = N2Africa, K = Kenya
Entry: strain number in chronological order
Contributor: Organization holding isolate, MIR = Nairobi MIRCEN
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 bromothiol 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

Response of soybean, bush bean and climbing bean grain yield to inoculation (I) and/or P fertilization (P), relative to the yield in the control plot without inputs, in the agronomy trials in Western Kenya in 2010 long rains and short rains and 2011 long rains.

Figure 1. Inoculation response of five soybean varieties as observed at Bughore site in DR Congo during 2011 long rains growing season.

Figure 2. Interaction between inoculation and phosphorus addition to climbing bean at Nemba site in northern Rwanda (red is + inoculum) during 2010 long rains season.
When the situation is not known, a field test to determine the need for inoculation is recommended. Three basic treatments are needed:

- Inoculated plants with the best inoculant available.
- Non-inoculated plants receiving no fertilizer treatment.
- Non-inoculated plants furnished with fertilizer nitrogen

These three treatments may be examined at two soil fertility levels.

Capacity has been built through working with government extension workers, researchers, master farmers, follower farmers and other partners like AGRA and TL II for agronomic research and data collection.

Field days and demonstrations are conducted on N2Africa agronomy trial sites. Effective demand is created for N2Africa technologies (especially seeds, inoculants and fertilizers) from local farmers involved in the research in particular, and the surrounding local communities in general. Data collection entry and subsequent analysis are for be done for best-fit variety and input trials.

Number of varieties by legume type that are undergoing evaluation for BNF potential in different countries.

<table>
<thead>
<tr>
<th>country</th>
<th>soybean</th>
<th>bean</th>
<th>cowpea</th>
<th>groundnut</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>DR Congo</td>
<td>10</td>
<td>12</td>
<td>0</td>
<td>4</td>
<td>26</td>
</tr>
<tr>
<td>Ghana</td>
<td>7</td>
<td>0</td>
<td>9</td>
<td>6</td>
<td>22</td>
</tr>
<tr>
<td>Kenya</td>
<td>14</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>Malawi</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Nigeria</td>
<td>11</td>
<td>0</td>
<td>8</td>
<td>4</td>
<td>23</td>
</tr>
<tr>
<td>Rwanda</td>
<td>13</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>6</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td>74</td>
<td>47</td>
<td>20</td>
<td>22</td>
<td>1647</td>
</tr>
</tbody>
</table>

Soils representing different agro-ecological zones sampled from across chosen sites

Agronomic trials set-up and underway to find best fit varieties and inputs of N2Africa mandate legumes in the different N2Africa mandate
Agronomy

N2Africa is establishing a baseline of BNF status, niches for N2 fixing legumes, and a system of monitoring, evaluation and impact assessment in all its focus working areas

Monitoring Implementation: Example Case Story

Mrs Hassan from Malawi: a success story since the first season of N2Africa, handling one full soybean variety trial with three replications on her own, her trial is one of the most well managed in the 2011/2012 season and is expecting to give one of the highest yields. Having undergone two N2Africa trainings on inoculants technology and field management under both research and dissemination, she is now an advocate for inoculants technology in her community, and many people are interested in N2Africa technologies because of her good and highly visible N2Africa trials.

Farmer Hassan helping with the implementation of soybean agronomy trials conducted on her farm.
N2Africa Project Outcomes

- Diversification of N2-fixing legume species that are integrated into smallholder farming systems in sub-Saharan Africa;
- Expansion in cultivation of grain and forage legumes, greater productivity in legume-based farming systems, and enhanced family incomes;
- Selection of efficient rhizobial inoculant strains and improved grain legume varieties with enhanced BNF capacities adapted to various environmental stresses;
- Establishment of a state-of-the-art laboratory and culture collection of elite strains of rhizobia for target legumes; and
- Establishment of rhizobial inoculant production in countries of West, East and Southern Africa, through partnership with the private sector.

Original and revised dissemination targets over the project’s four years.

<table>
<thead>
<tr>
<th>Year</th>
<th>Original Dissemination</th>
<th>Revised Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Targets</td>
<td>per year cumulative</td>
<td>Targets</td>
</tr>
<tr>
<td>1</td>
<td>18000</td>
<td>20000</td>
</tr>
<tr>
<td>2</td>
<td>11000</td>
<td>15000</td>
</tr>
<tr>
<td>3</td>
<td>11000</td>
<td>15000</td>
</tr>
<tr>
<td>4</td>
<td>3000</td>
<td>6000</td>
</tr>
</tbody>
</table>

MSc Students Sponsored by N2Africa

Country | Name | Status
--- | --- | ---
DRC | Bintu Ndusha Nabintu | Field work
Eric Sika Terrorma | Coursework
Fidel Bartheba Bngaliza | Coursework
Balume Kayani Isaac | Field work
Ghana | Jacob Uzien | Coursework
Abdul-Aziz Abdul-Latif | Coursework
Kenya | Maureen Waswa | Fieldwork
Anne Wekesa | Field work
John Oduku Omondi | Fieldwork
Malawi | Esnart Nyirenda | Coursework
Donald Siyeni | Coursework/Fieldwork
Mônea Linda Mucaveja | Admitted
Fernando João Susalei | Admitted
Nigeria | Fatima Aibin Abubakar | Coursework
Vida Peter | Coursework
Rwanda | Domitille Mukanibante | Coursework
Alfred Rumonge Tabaro | Coursework
Zimbabwe | Tatenda Kainga | Fieldwork
Silbonginkosi Dzunywa | Fieldwork

Research topics and status of PhD students participating in the N2Africa Project as of Month 30 (April 2012)

<table>
<thead>
<tr>
<th>Country</th>
<th>Research Topic</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghana</td>
<td>1 (D)</td>
<td>Kwame Nkrumah University of Science and Technology/WU</td>
</tr>
<tr>
<td>Kenya</td>
<td>1 (C)</td>
<td>Wageningen University (WU)</td>
</tr>
<tr>
<td>Malawi</td>
<td>1 (F)</td>
<td>Londrina, Univ. Brazil</td>
</tr>
<tr>
<td>Nigeria</td>
<td>1</td>
<td>Murdoch University</td>
</tr>
<tr>
<td>Rwanda</td>
<td>1</td>
<td>Wageningen University (WU)</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>1</td>
<td>Murdoch University</td>
</tr>
</tbody>
</table>

Performance of the N2Africa Project based on 29 quantitative parameters through Year 2.

Goal | Unit | Source | Milestone | %
--- | --- | --- | --- | ---
Conduct Master Farmer workshops | no | Milestone 3.2.2 | 320 | 1766 | 552% |
Identify promising soybean varieties | no | Milestone 2.1.1 | 10 | 27 | 270% |
Conduct three extension events per season | no | Milestone 4.4.3 | 66 | 175 | 265% |
Identify promising bean varieties | no | Milestone 2.2.1 | 6 | 12 | 200% |
Identify promising gnot&coepa varieties | no | Milestone 2.3.1 | 12 | 21 | 175% |
Conduct annual events on human nutrition | no | Milestone 4.5.3 | 32 | 53 | 166% |
Develop dissemination tools | no | Milestone 4.2.1 | 24 | 39 | 163% |
Engage Action Sites (communities) | no | Milestone 1.2.2 | 80 | 128 | 160% |
Conduct adaptive research campaigns | no | Milestone 2.5.1 | 27 | 43 | 159% |
Increase BNF by grain legumes | kg | Vision Statement | 46 | 66 | 144% |
Conduct grassroots training | no | Milestone 5.4.1 | 56500 | 67109 | 119% |
Train MSc candidates | no | Milestone 5.2.1 | 16 | 19 | 112% |
Reach rural households by Year 2 | no | Milestone 5.2.1 | 56500 | 67237 | 119% |
Involve women in all farmer-related activities | % | Milestone 4.5.2 | 48 | 50 | 96% |
Conduct three media events per year | no | Milestone 4.4.4 | 48 | 46 | 96% |
Communities produce improved legume seed | % | Milestone 4.3.2 | 50 | 44 | 88% |
Upgrade rhizobiology laboratories | no | Milestone 3.4.2 | 8 | 7 | 88% |
Communities linked to legume markets | % | Milestone 4.3.3 | 50 | 44 | 87% |
Explore tree & forage legumes | no | Milestone 2.4.1 | 18 | 14 | 78% |
Train technical staff in rhizobiology | no | Milestone 5.1.1 | 32 | 23 | 72% |
Increase legume grain yield | kg/ha | Vision Statement | 954 | 630 | 66% |
Conduct annual short courses (participants) | no | Milestone 5.1.2 | 30 | 13 | 43% |
Train agro-dealers in BNP products | no | Milestone 5.4.3 | 80 | 25 | 31% |
Isolate and screen native rhizobia | no | Milestone 3.1.3 | 2000 | 624 | 321% |
Train PhD candidate | no | Milestone 5.2.1 | 8 | 2 | 25% |
Commercialize inoculant distribution | no | Milestone 3.4.3 | 150000 | 31759 | 21% |
Increase rhizobium inoculation | S/yr | Vision Statement | 130 | 20 | 16% |
Conduct MNP counts | no | Milestone 3.1.2 | 400 | 59 | 15% |
Select candidate strains for field testing | no | Milestone 3.1.3 | 100 | 8 | 8% |
Average performance | 120% |

How to increase the inputs from biological nitrogen fixation

- Increase the area of land cropped with legumes (targeting of technologies)
- Increase legume productivity through better management and fertilizer
- Select better rhizobium strains and inoculate
- Link to markets and create new enterprises to increase demand for legumes

Grain legume production strategies

1. Intercropping

- Simple innovations in maize-legume intercropping permit farmers to grow a wider range of food legumes as under-storey intercrops with cereals.
- The most common intercropping practice is to alternate maize and pigeon pea or cowpeas, either between or within rows. These legumes mature quickly and can tolerate shading, but yields are low.
- Alternatively, cereals may be planted at their recommended population, but every-other row is shifted to provide a wider maize population, but maintaining similar yields.

2. Rotation

- Legumes may be grown in rotation with other crops one in three or four seasons (e.g. L-M-M-L-M-M-M) in monomodal climates or every other season in bimodal rainfall conditions (M-L-M-L).
- Cereal-legume rotation replenishes soil nutrients and improves the availability of organic resources, particularly when legume varieties have traits appreciated by farmers.
- Strong commercial demand for legumes further justifies targeted investment into crop rotation.
- Promiscuous soybean and the dual-purpose cowpea lines available to farmers in West Africa produce about 2.5 t of grain, 2.5 to 4.1 of forage, 5 kg between 44 and 103 kg N and have a positive N balance of 43 kg N ha⁻¹. Growing maize after soybean improves grain yield 2.5-fold.
- Legume rotations may be intercropped at both stages, such as maize-cowpea followed by groundnut-pigeon pea.
- Widespread adoption of cereal-legume rotation is supported by farming systems.

3. Relay Cropping

- Different approaches permit more productive intercropping with groundnut, green gram, soybean and other higher-value food legumes that are not otherwise intercropped with maize because of excessive shading.
- Intercropping also permits cultivation of legumes that suppress Shiga such as Lablab and Desmodium.
- Also useful example of intercropping is upland rice and soybean where soybeans reduced bird damage to rice.
- When maize and pigeon pea are intercropped, maize is harvested first and pigeon pea grows for several more months, producing a complete canopy cover and yields of up to 1.5 t ha⁻¹.

Inoculant packets deployed by the project through Year 2.

<table>
<thead>
<tr>
<th>Country</th>
<th>Hub Status</th>
<th>Target (n)</th>
<th>Realized (n)</th>
<th>Achieved (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghana</td>
<td>WA imported</td>
<td>25000</td>
<td>2304</td>
<td>9.2</td>
</tr>
<tr>
<td>Nigeria</td>
<td>WA imported</td>
<td>25000</td>
<td>1200</td>
<td>4.8</td>
</tr>
<tr>
<td>Malawi</td>
<td>SA imported</td>
<td>16667</td>
<td>140</td>
<td>0.9</td>
</tr>
<tr>
<td>Mozambique</td>
<td>SA imported</td>
<td>16667</td>
<td>550</td>
<td>3.3</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>SA produced</td>
<td>16666</td>
<td>1230</td>
<td>7.4</td>
</tr>
<tr>
<td>DR Congo</td>
<td>ECA imported</td>
<td>12500</td>
<td>8606</td>
<td>70.4</td>
</tr>
<tr>
<td>Kenya</td>
<td>ECA produced</td>
<td>25000</td>
<td>15784</td>
<td>63.1</td>
</tr>
<tr>
<td>Rwanda</td>
<td>ECA imported</td>
<td>12500</td>
<td>1745</td>
<td>14.0</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td>150000</td>
<td>31759</td>
<td>21.2%</td>
</tr>
</tbody>
</table>

Estimated production costs of soybean in west Kenya during the 2011 long rains growing season.

<table>
<thead>
<tr>
<th>Management</th>
<th>Seed &amp; inoculant</th>
<th>Fertilizer &amp; fungicide</th>
<th>Labor</th>
<th>Bagging</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB19 spraying only</td>
<td>40</td>
<td>46</td>
<td>87</td>
<td>5</td>
<td>178</td>
</tr>
<tr>
<td>SB19 SSP no BIOFIX</td>
<td>40</td>
<td>107</td>
<td>90</td>
<td>6</td>
<td>243</td>
</tr>
<tr>
<td>SB19 SSP w/BIOFIX</td>
<td>62</td>
<td>107</td>
<td>91</td>
<td>8</td>
<td>268</td>
</tr>
<tr>
<td>SB19 Sympal w/BIOFIX</td>
<td>62</td>
<td>119</td>
<td>93</td>
<td>11</td>
<td>285</td>
</tr>
</tbody>
</table>

Grain yield and economic returns to soybean production in west Kenya during the 2011 long rains growing season (based on 26 farms).