THIN AIR NITROGEN SOLUTIONS, LLC

PROJECT IMPLEMENTATION PLAN

Submitted to USAID DIV in March 2012

Background Information

Since our proposal was submitted, we have established a research partnership with Hawassa University in Ethiopia. In particular, through other funding we currently have three graduate students doing their thesis research on cyanobacterial bio-fertilizer production and utilization. Two additional students will be selected to join our research team at Hawassa University to focus on this USAID DIV project.

In addition, we have initiated an Ethiopian cyanobacterial culture collection and begun evaluation of those cultures. We are in the process of selecting the cyanobacterial culture that we will use as we scale-up. Criteria for selection include the growth and N fixation rates. Based on our recent tests, the E-3 culture has the best growth rate (see Figure 1 below). Microcystins and saxitoxins have been measured in the Ethiopian cultures, and no measurable levels of cyanotoxins were found in any of the cultures.

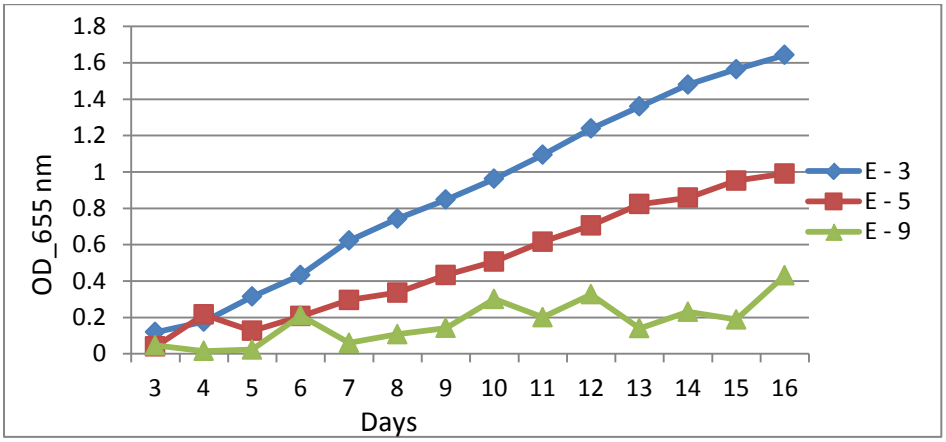


Fig. 1. Growth of three Ethiopian cyanobacteria strains in Allen-Arnon media.

We are also evaluating different water sources that may be available to farmers in the area for use in the ponds including groundwater, river water, and water from Lake Hawassa. The experimental setup is shown in Figure 2, and to date, the river water seems to provide the best growth.

We have begun prototype development of the production system in the USA (Figure 3), and are eager to develop a prototype specifically for the Ethiopian environment using local materials.

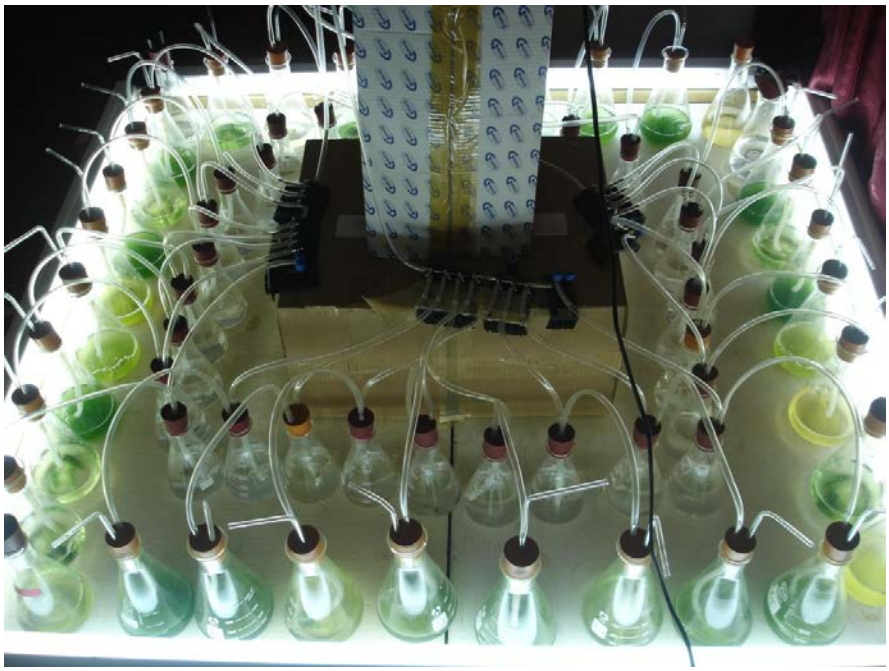


Fig. 2. Experimental setup for water study.

Fig. 3. Pond prototype tested on-farm in the USA in 2011.

Timeline

Tasks have been defined for each objective, and a timeline developed for their completion.

Objective	Task	Description	Estimated Completion Date
1. Measure the yield impact of bio-fertilizer nitrogen as compared to urea and compost	1.1	Select Farms and Crops for Field Studies	6/30/12
	1.2	Initiate Field Studies	9/30/12
	1.3	Harvest Field Studies	12/31/12
	1.4	Data Analysis	3/31/13
2. Calculate costs, benefits, economic feasibility, and cost effectiveness of bio-fertilizer production in Ethiopia	2.1	Pond Construction Costs Determined	6/30/12
	2.2	Production Potential and Cost Effectiveness Estimated	9/30/12
	2.3	Supply Side Factors Evaluated	12/31/12
	2.4	Data Analysis	3/31/13
3. Develop and test training materials, distribution channels, and branding strategies	3.1	Branding Strategies Developed	6/30/12
	3.2	Distribution Channels Defined	9/30/12
	3.3	Training Materials Drafted	12/31/12
	3.4	Training Materials Tested and Revised	3/31/13
4. Summarize research results into a list of recommendations for future scale-up of technology and dissemination through Ethiopian entrepreneurs	4.1	List of Recommendations for Future Scale-up Drafted	12/31/12
	4.2	List of Recommendations for Future Scale-up Finalized	3/31/13

Environmental Monitoring and Mitigation Plan

Toxicity

Some cyanobacteria possess the potential to produce toxins. For this reason, much work has been done on the mitigation and control of harmful algal blooms. Not all cyanobacteria have toxin-producing genes, and of those that do, conditions must be appropriate for toxin production to occur. Recent research suggests that for toxins to be produced, nutrients must be in excess. The culture conditions that we will employ in the laboratory and in the field do not supply any organic carbon or combined nitrogen. Rather these elements are fixed from nitrogen and carbon dioxide in the atmosphere through the processes of N-fixation and photosynthesis. So in addition to optimizing photosynthesis and N-fixation, the culture conditions employed will reduce the potential for toxin production. To ensure the absence of any cyanotoxin production, fertilizer will be tested using commercially available cyanotoxin assay kits.

In addition, we have tested our most promising Ethiopian cultures for cyanotoxins, and none of them had detectable levels of microsystins or saxitoxins. Therefore, the spread of a toxic algal

bloom from our bio-fertilizer ponds into the natural environment is highly unlikely. Accidental release prevention and routine contaminant testing are necessary to maintain public trust, and are an integral part of the Thin Air Nitrogen Solutions quality assurance/quality control framework.

Invasiveness

When non-native organisms are grown in an area, there is potential for the new organism to become invasive, taking over and out-competing other plants. However, in our approach we plan to mass-cultivate native Ethiopian strains of N-fixing cyanobacteria, currently growing in our lab, rather than apply an approach where foreign organisms are introduced to a new environment, where their potential to be invasive is unknown. We have isolated N-fixing strains from around Ethiopia. Strains that were sampled from a particular location will be cultivated in that area. This approach has been successful in mass cultivation of algae for biofuel production. In addition to combating invasiveness, it has proven more successful since native organisms tend to take over laboratory cultures.

The cyanobacteria we are using are native to Ethiopia, having been cultured from soils collected there. Therefore, if they "escaped" from ponds and were able to flourish in natural systems, they are not an invasive group of species. Though escape is possible through overflowing of a pond, for example, their potential to flourish in the natural ecosystem is very low. In the production ponds, we supply the required nutrients in just the right amounts, and we mix/aerate and provide CO_2 to optimize growth conditions. Under natural conditions, the cyanobacteria must compete with all other soil biota. They are not great competitors in the soil environment; therefore, upon accidental release, they are likely to go back to steady-state conditions in which they usually exist in Ethiopian soils.

Runoff

Nutrient runoff (nitrogen and phosphorus) is a serious concern, especially in heavily fertilized fields on sloping lands. Cyanobacterial bio-fertilizer is expected to act like a slow-release N source, moderate in the speed of release as compared to urea and compost (research is currently underway to evaluate this). Since bio-fertilizer is likely to be applied at low to medium application rates (not excessive rates), and it acts like a slow-release fertilizer, the potential for nutrient runoff is small. When applying the solid bio-fertilizer to soil, farmers will be trained to apply the fertilizer below-ground near the seed (about 2 inches away) which reduces the potential for nutrient runoff. In addition, if the cyanobacterial bio-fertilizer is applied as needed through an irrigation system, the risk of nutrient runoff is reduced due to the more precise application of nitrogen and higher nitrogen use efficiency in such a system. Thin Air Nitrogen Solutions will provide training to farmers not only on how to produce cyanobacterial bio-fertilizer, but also how to utilize it to achieve the greatest impact on crop yields and to minimize the potential for nutrient runoff.

Mosquitoes

The initial ponds are being constructed at Hawassa University as part of a grant from the National Collegiate Inventors and Innovators Alliance. We will not be moving to on-farm ponds until we

receive additional funding (beyond this Phase I DIV grant). Since the ponds will be mixed, not stagnant, we are not expecting mosquito breeding to be a concern. However, if we notice that mosquitoes are breeding in the ponds, we plan to use mosquito netting over the ponds. If necessary, we plan to use Pramex Long-lasting Insecticidal Nets. They are impregnated with permethrin, and their EPA registration number is 73049-433. More information can be found here: http://www.pramexnet.com/static.asp?path=2887 . In any case, we will only use World Health Organization recommended nets and will follow recommended net disposal methods in order to minimize any negative human or environmental consequences.

Action Plan

- ✓ Measure cyanotoxin levels in cyanobacteria prior to pond seeding and crop fertilization to verify their absence.
- ✓ Use only local Ethiopian cyanobacteria in outdoor ponds and fertilizer efficacy trials.
- ✓ Train farmers to utilize cyanobacterial bio-fertilizer in ways that optimize effectiveness and minimize runoff risk.
- ✓ Evaluate ponds for presence of mosquitoes weekly and respond accordingly.

Thin Air Nitrogen Solutions
Grant No. AID-OAA-G-12-00015

Progress Report to USAID- DIV **June 30, 2012**

Task 1.1 Select Farms and Crops for Field Studies

Two graduate students (Francis Abuye and Muluneh Menamo) in the School of Plant and Horticultural Sciences at Hawassa University were selected to work on the cyanobacterial bio-fertilizer project (based on their BS grade point average, 1st semester MS grades, interest, and class activities). One student will focus on maize and the other on kale in their field studies in the upcoming cropping season (beginning in July/August—October/November). Maize and kale are common and important crops in southern Ethiopia.

We are in the process of negotiating lease arrangements with farmers in Chefe, a village near the city of Awassa, in order to conduct experiments in collaboration with farmers. The on-farm placement of these trials is crucial due to the importance of understanding farmers' constraints and attitudes. We will compare five fertilizer treatments (dried cyanobacterial bio-fertilizer, liquid cyanobacterial bio-fertilizer, compost, urea, and a no-fertilizer control) in replicated trials. Field plot size will be 3m x 1.75m (5 rows of 0.75m inter-row & 0.25m intra-row spacing) for maize and 2m x 1.75m (5 rows of 0.50m inter-row & 0.25 m intra-row spacing) for kale.

Based on results from our laboratory investigations and recent results in the hoop house, we have optimized cyanobacterial bio-fertilizer production in small ponds. Thus, it is possible for us to produce sufficient amounts of cyanobacterial bio-fertilizer for use in the field studies (for both dry and liquid application treatments) within six weeks by using the 12 ponds in the hoop house on the Hawassa University campus.

Task 2.1 Pond Construction Costs Determined

Pond construction costs were calculated for the small 3 m^2 ponds we are using to optimize the bio-fertilizer production system. The costs of hoop house and raceway construction, lining (with plastic sheets), and aeration (using a compressor for experimental ponds) were included; the materials used to construct the pond are listed in Table 1.

In addition, rough estimates for up-scaling have also been completed (Table 2). The estimates are for two different raceway sizes: medium (12 m^2) and large (250 m^2). The large pond size is 1/10 timad (local unit of area measurement), and a timad is ¼ hectare. The data in Table 2 are rough estimates with the medium raceway estimated at $277 and the large one at $5718. Since our goal is that small farmers could begin using this system on their own farms for less than a $100 investment, we will be diligently working on reducing costs as we move forward. For example, the aeration system will be changed to a paddle wheel made with locally available materials and powered with a lift system (similar to the weights on a cuckoo clock).

Table 1. Cost breakdown for construction of 13 test ponds (1.5 x 2 m each). Costs are given in Ethiopian Birr (ETB, currently 17.7 ETB per 1 USD).

Itemized Breakdown	Costs (ETB)
Hoop house construction	
Round wood	7000
Transparent plastic sheet	3552
TOTAL	10,552
Pond construction	
Lumber	3000
Nails	1000
Chip wood	4800
Round wood	2820
Pond lining	5264
TOTAL	16,884
Pond accessories	
Hose	2500
Elbow joint	1120
Get valve	3000
T-joint	1233
Nipples	1200
Teflon	999
PPR pipe	4000
Socket	888
Ball valve	2452
Compressor	12,000
TOTAL	29,392
Carpentry	2000
Plumbing	3462
GRAND TOTAL	62,290
Cost per pond	4792
	($271)

Table 2. Cost estimates for medium (2 x 6 m = 12 m^2) and large (0.1 timad = 250 m^2) scale raceways. Costs are given in Ethiopian Birr (ETB, currently 17.7 ETB per 1 USD).

Itemized costs	Medium	Large
	ETB	
Clearing and site preparation	400	8000
Pond construction	1900	40,000
Pond accessories	1450	30,000
Labor	500	10,000
Contingency (15%)	650	13,200
TOTAL	4900 ($277)	101,200 ($5718)

Note: A 15% contingency is included to cover unforeseen costs.

Task 3.1 Branding Strategies Developed

Thin Air Nitrogen Solutions is a US-based company, and we plan to establish an Ethiopian-based company called Blue Green Africa. Blue Green Africa's image will be of professionalism and empowerment of Ethiopian entrepreneurs. We have designed a logo (as seen below), and this logo will be utilized on our buildings, vehicles (motorcycles and pickup trucks), and supplies. In addition, employees will wear blue-green tie-dyed shirts and baseball caps with the Blue Green Africa logo on them. The tagline will be "Fertilizer to Feed Your Family".

In addition, when BGA Bio-fertilizer producers choose to sell the product to other farmers, they will participate in our Quality Assurance/Quality Control program, and when all standards for fertilizer

quality are met, they will receive Blue Green Africa bags in which to store and sell the fertilizer. Bags will include the logo and tagline.

Blue Green Africa's advertising will follow a multi-pronged approach: field demonstrations, radio, video, and billboards. At the beginning (even prior to launch), and later when we expand into new territory, we will install field demonstrations at early-adopter farms. Early adopters will be given a 30% discount in exchange for their willingness to host field days for neighboring farmers to come and see the BGA Bio-fertilizer production process for themselves. Farmer-to-farmer communication will be the primary mode of communication at field days, because the level of trust and confidence is high between farmers.

We will run radio spots three times a week for the first month after launch and weekly thereafter. In addition, we will make a video explaining the fertilizer production process and interviewing early adopters, and then show this video in villages throughout southern Ethiopia using mobile battery-powered projection equipment.

We will also create billboards at the entrances to the major market towns in the area to increase brand recognition and identification of Blue Green Africa as a company that empowers local entrepreneurs to feed their families. To network with customers, we will develop displays to show on regional market days. These displays will have minimal written language (tagline only) and focus on illustrations that present the basic idea of Blue Green Africa and the potential benefits to families.

A training manual will be developed for both prospects and customers. The manual will provide all directions for BGA Bio-fertilizer production and utilization using only illustrations and numbers. This is critical due to the high illiteracy rate in rural Ethiopia, especially among women. Even for literate people, 56 different languages are in common use in the Southern Nations, Nationalities, and Peoples region of Ethiopia where we are initiating our business. The manual will include information on the investment required, opportunities for credit, and Return on Investment and breakeven expectations.

Tasks for the Next Quarter

Task 1.2. Initiate field studies.

Task 2.2. Production potential and cost effectiveness estimated.

Task 3.2. Distribution channels defined.

Thin Air Nitrogen Solutions
Grant No. AID-OAA-G-12-00015

Progress Report to USAID- DIV **October 25, 2012**

Task 1.2 Initiate Field Studies

According to the original schedule, we had planned to initiate field studies in Chefe, a village near the city of Awassa, in the previous quarter. However, due to inadequate production of bio-fertilizer for a field-scale experiment and an unexpectedly long rainy season in southern Ethiopia, we decided to test crop responses to cyanobacterial bio-fertilizer through greenhouse studies at this time.

M.Sc. students at Hawassa University have initiated three greenhouse studies evaluating cyanobacterial bio-fertilizer impact on kale, maize, and chili pepper. These crops were chosen because of their importance in southern Ethiopia. Government-recommended fertilizer rates are being used for each crop, and two soils (an acidic soil from Yirgalem and an alkaline soil from Ziway) are being tested, as well. Cyanobacterial bio-fertilizer has been applied in either solid or liquid form, and in addition to a no-fertilizer control, urea has also been applied at the same nitrogen rate for comparison purposes.

The maize and kale experiments have recently been harvested, and the chili pepper study will be harvested soon. In the next quarter, the students will be finishing up these experiments and analyzing their data.

Graduate students with their greenhouse studies evaluating cyanobacterial bio-fertilizer in comparison with urea.

A) Girma Wolde and his maize experiment.

B) Mulatu Asmamaw with his kale experiment.

C) Mekiso Yohannes with his experiment on chili peppers.

Task 2.2 Production Potential and Cost Effectiveness Determined

Production Potential

Based on our 1 x 2 m prototype ponds, we have calculated the production potential from full-size prototypes. The small ponds (300-L) yielded 28.2 mg N/ L in a 3-week growth period during a cool, cloudy season. We expect to be able to produce cyanobacterial bio-fertilizer year-round in southern Ethiopia, and we predict that bio-fertilizer yields will be higher during warmer, dryer seasons. Nonetheless, we used these measured values to calculate production potential in order to be conservative in our calculations.

Based on an average need of 50 kg N for a hectare of vegetable production, we would need to set aside about 6.8% of a hectare in order to produce enough N fertilizer to grow a full hectare of vegetables. This is better than our original predictions of 10%, so we are pleased with this level of productivity, and we expect to improve productivity further in future months as we optimize the production system.

The N content of the dried cyanobacteria was measured to be 3.04% N. This is about three times the N content of compost or manure, but is less than half of the N contents we have measured in cyanobacteria cultures from the U.S.A. Therefore, we will continue to collect and evaluate Ethiopian cyanobacteria in order to select cultures with the fastest growth rates and highest N contents.

Cost Effectiveness

When we began working in Ethiopia in 2010, the cost of 50 kg of urea fertilizer (46% N) was 350 birr or $25. That was already two to three times the cost of urea in the U.S.A. Due to widespread inflation in Ethiopia and reduced exchange rates with the USD, today's price is 631 birr or $35 for 50 kg. Since only 46% of urea is actually N, in order to buy 50 kg N for a hectare of vegetables, an Ethiopian farmer would have to pay 1372 birr or $77 (not including transportation costs).

The primary challenge for cyanobacterial bio-fertilizer production to be able to produce N fertilizer more cheaply than urea, is the cost of construction of the production ponds. After construction, the cost for consumables and labor is minor, but we are continuing to work on reducing pond construction costs in order to achieve profitability for cyanobacterial bio-fertilizer.

Yield Impacts

Based on a recent greenhouse study in the U.S.A. on lettuce, the application of liquid cyanobacterial bio-fertilizer to two different soils at 50 kg N/ha resulted in average yields that increased by 106%. In other words, the average yield more than doubled. For the sake of this example, we will assume that the same application rate would double yields of crops commonly grown in Ethiopia: kale, maize, and chili peppers. Our greenhouse studies currently in place in Ethiopia will allow us to improve our estimates once they are completed.

Table 1. Typical yields and prices for Ethiopian crops.

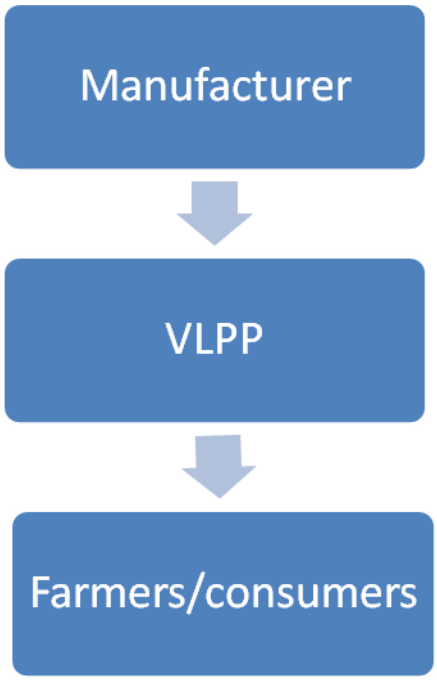
Crop	Typical Yield (kg/ha)	Current Retail Price in SNNP (ETB/kg)
Kale	1380	5
Maize	1700	7
Chili Pepper	1300	17

SNNP is the Southern Nations Nationalities and Peoples Region of southern Ethiopia.
ETB stands for Ethiopian birr.

Based on the data in Table 1, if we assume that cyanobacterial bio-fertilizer would double yield, the additional income to the farmer would be 6,900 birr/ha ($385/ha), 11,900 birr/ha ($665/ha), and 22,100 birr/ha ($1,235/ha) for kale, maize, and pepper, respectively. At a cost of $77/ha for urea, there is a clear profit potential here, especially if we can produce cyanobacterial bio-fertilizer for less than the cost of urea.

Task 3.2 Distribution Channels Defined

Efficient distribution channels are critical to being able to deliver products and services to consumers quickly and cheaply. We are currently evaluating two different approaches for our business model and product distribution. Our original business model is based on empowering farmers to produce fertilizer on-farm through provision of goods (start-up kits, consumables) and services (training, troubleshooting). In this model, we will sell goods and services directly to the consumer rather than through retailers. However, we are planning to use Village-Level Product Promoters (VLPP) who are early-adopter farmers, and who also serve as the Thin Air front line sales and field staff. The VLPPs will demonstrate the fertilizer production system on their own farms for neighboring farmers to learn about and evaluate and also serve as technical experts for their neighbors. The VLPPs will make the distribution and sales processes more efficient and effective since they will play an important role in mobilizing smallholder farmers since they are trusted members of the farming community. In this model, Thin Air Nitrogen Solutions would utilize the marketing channel diagrammed below. Pickup trucks will be utilized for delivery of start-up kits, but motorcycles could be used for delivery of consumables and troubleshooting services.



Recently, we have begun to reconsider the original business model for several reasons. First, having farmers as fertilizer producers requires them to take a fair amount of risk on an unknown (and currently unproven) process. This is not a reasonable expectation for low-resource farmers. Secondly, there are issues regarding power (to turn the paddlewheel) and water availability that may restrict the locations where on-farm bio-fertilizer production is feasible. These concerns have led us to develop a new business model based on a distributed network of "Fertilizer Farms." These would be placed throughout the countryside on the outskirts of the woredas (similar to county seats) in order to maintain the benefits of reduced transportation and improved access for rural farmers. The Fertilizer Farms would sell cyanobacterial bio-fertilizer directly to farmers, with primary sales occurring on market days from a booth, but additional sales could be made directly from the Fertilizer Farms. A portion of each Fertilizer Farm would be set aside for demonstration purposes so that farmers can see the impact of the fertilizer for themselves. We do not expect that VLPPs would be necessary in this model.

We are planning to request funds to evaluate these two different business models and their potential for development impact in our DIV Phase II proposal.

Tasks for the Next Quarter

Task 1.3. Harvest Field Studies.—This task has been changed to analyze greenhouse studies on maize, kale, and chili peppers and initiate additional greenhouse studies on lettuce and tomato.

Task 2.3. Supply Side Factors Evaluated.

Task 3.3. Training Materials Drafted.

Task 4.1. List of Recommendations for Future Scale-Up Drafted.

Thin Air Nitrogen Solutions
Grant No. AID-OAA-G-12-00015

Progress Report to USAID- DIV **January 8, 2013**

Task 1.3 Analyze Greenhouse Studies on Maize, Kale, and Chili Peppers and Initiate Greenhouse Studies on Lettuce and Tomato

The greenhouse studies on kale, maize, and chili pepper were completed. Each crop was tested on soil types: Ziway (pH 5.8) and Yirgalem (pH 8.2). There were three fertilizer treatments (urea, dry cyanobacteria, and liquid cyanobacteria) all applied at the same N rate and a no-fertilizer control. All experimental plants from the three experiments were harvested, and yield data were measured, recorded, analyzed and summarized. Laboratory analyses were made for soil and plant N contents. Results were analyzed, and first drafts of the theses (on Kale and Pepper) have been prepared and are now under review.

The urea, dry cyanobacterial bio-fertilizer, and liquid cyanobacterial bio-fertilizer consistently improved plant growth characteristics in kale, maize, and chili peppers as compared to the no-fertilizer control (Table 1). In both kale and maize, the dry cyanobacterial bio-fertilizer resulted in plant heights, leaf areas, short dry weights, root dry weights, and leaf N concentrations equal to the urea treatment applied at the same N rate. However, in chili pepper the dry cyanobacterial bio-fertilizer treatment consistently outperformed the urea treatment.

For most parameters measured in the kale and maize experiments, the liquid cyanobacterial bio-fertilizer did not perform as well as either the urea or dry cyanobacterial bio-fertilizer treatments. However, in the chili peppers, the liquid cyanobacterial bio-fertilizer achieved plant growth parameters equal to those achieved with urea, but less than those measured in plants receiving dry cyanobacterial bio-fertilizer.

In addition, soil N contents at the end of the experiment were significantly higher in the dry cyanobacterial bio-fertilizer treatment in all three crops, apparently due to continued N fixation by cyanobacteria after application to the pots. This was also true for the liquid cyanobacterial bio-fertilizer in the kale and maize experiments.

Overall, this data clearly documents the benefits of cyanobacterial bio-fertilizer, particularly when applied to the soil in dry form.

Table 1. Plant characteristics and leaf and soil N contents of three crops grown on two soils under greenhouse conditions using different fertilizer treatments.

Fertilizer Treatment	Plant Height	Leaf Area	Shoot Dry Weight	Root Dry Weight	Leaf N	Soil N
	--cm--	--cm^2--	--------g--------		--------%--------	
			kale			
Control	29.25[c]	261.31[c]	1.98[c]	0.36[c]	4.16[c]	0.15[c]
Urea	38.50[a]	628.95[a]	4.29[a]	0.89[a]	6.14[a]	0.23[b]
Dry Cyanos	39.96[a]	647.67[a]	4.38[a]	1.01[a]	6.47[a]	0.27[a]
Liquid Cyanos	34.89[b]	387.53[b]	3.19[b]	0.64[b]	5.46[b]	0.26[a]
			maize			
Control	32.4[c]	269.42[c]	1.24[c]	0.92[b]	2.16[c]	0.202[c]
Urea	41.5[ab]	525.67[a]	2.59[a]	1.58[a]	4.14[a]	0.218[b]
Dry Cyanos	45.0[a]	539.5[a]	2.82[a]	1.49[a]	4.47[a]	0.24[a]
Liquid Cyanos	39.9[b]	407.67[b]	2.32[b]	1.61[a]	3.46[b]	0.238[a]
			chili pepper			
Control	13.3[c]	161.2[c]	5.14[c]	0.9[c]	2.39[c]	0.151[c]
Urea	18.0[b]	326.9[b]	8.31[b]	1.96[b]	4.33[b]	0.254[b]
Dry Cyanos	22.67[a]	404.6[a]	13.95[a]	2.96[a]	5.25[a]	0.33[a]
Liquid Cyanos	18.83[b]	332.5[b]	9.49[b]	2.17[b]	4.55[b]	0.266[b]

Means followed by a common letter within a column are not significantly different at $p \leq 0.05$.

The new greenhouse experiments on lettuce and tomato plants are now in progress. We added compost as an additional treatment due to its widespread use in Ethiopia, along with urea. Lettuce plants are currently 8 weeks old and will be harvested soon. We are planning to keep growing the tomato plants until they produce fruit. The different treatments are already showing differences (Figures 1 and 2). It appears that both lettuce and tomato plants receiving the dry cyanobacterial bio-fertilizer treatment are showing superior growth in both soil types.

Figure 1. Lettuce growing in Ziway soil (A) and Yirgalem soil (B) 6 weeks after planting.

Figure 2. Tomatoes growing in Ziway soil (A) and Yirgalem soil (B) 6 weeks after planting. Note differences in flowering.

Task 2.3 Supply Side Factors Evaluated

Production Cost:
Supply is the quantity of good or service that a producer is willing and able to supply into the market at a given price in a given time period. Production cost is important to the supply side of the market. We base supply decisions on the cost of production. Production cost includes the opportunity cost of using the four factors of production (labor, materials, capital, and entrepreneurship).

- Labor: At the top of almost any list of business expenses are the wages paid to labor. This includes hourly wages, monthly salaries and fringe benefits. This will include metalworkers who build our paddlewheels on a contract basis and employees who make the nutrient solution and seed cultures and compile the start-up kits.
- Materials: Another noted expense for production operations is materials that make up the product. We are currently using materials imported from the USA to produce the nutrient solution, but efforts have begun to make the nutrient solution with local materials. This will reduce materials costs.
- Capital: The opportunity cost of using capital goods such as buildings, machinery, tools, vehicles, and assorted equipment. Building and land rental is likely to be our primary capital cost.
- Entrepreneurs: The organizing risk takers also incur an opportunity cost in the production of a good. The opportunity cost of entrepreneurial effort is profit.

Cost of Distribution:
The cost of distribution refers to the costs associated with moving a product from the production location to the point of consumption. This means the cost to move items from a warehouse to individual consumers. We will minimize the cost of distribution by empowering farmers to produce the product on their own farms for distribution to neighboring farmers. The use of Village Level Product Promoters will make the distribution and sales process more efficient and effective.

Delays in Transportation:
Transportation delays may result in customers' dissatisfaction due to lack of reliability. Pickup trucks will be utilized for delivery of start-up kits, and motorcycles will be used for delivery of consumables and troubleshooting services. We aim to move supplies to the Village Level Product Promoters as quickly and efficiently as possible.

Tax on Products:
Taxes on products, such as value added tax (VAT), have a direct effect on supply. Tax imposed on a product has an effect similar to that of a cost, which means that increased taxes affect the decision to supply, and how much to supply. In the Ethiopian context, VAT is payable if supplies are made in Ethiopia.

The Number of Consumers in the Market:
If more people want a product, it is in greater demand, and the price is higher; if less people want it, the opposite is true. In other words, the number of consumers affects production. Our marketing plan aims to increase the consumer numbers as a percentage of the total number of smallholder farmers in southern Ethiopia.

The Price of the Factors of Production:
If input prices go up, the cost of producing the goods increases. At each price, producers need to sell their goods for more money. So an increase in the price of inputs leads to a decrease in supply. Similarly, a decrease in the price of inputs leads to an increase in supply. Important inputs for bio-fertilizer production include plastic for pond lining and metal for paddlewheel construction.

The Number of Suppliers:
The number of producers in the market has a direct effect on the amount of a product that producers are willing and able to sell. More competition usually results in a reduction in supply, while less competition gives the producer an opportunity to have a bigger market share with a large supply. We will be developing a network of metalworkers and sources of plastic liners in order to minimize our risk and increase our leverage in the marketplace.

Demand for Raw Materials:
When the price of raw materials increases, there will be less supply and the cost of the products will increase. On the other hand, the demand for the product will decrease because of the increase in cost. The metal used in paddlewheel construction could be considered a raw material; its price will be important to our profitability and sustainability.

Natural Climate:
Favorable weather will produce a bumper crop of bio-fertilizer and will increase supply. Unfavorable weather conditions will lead to a poorer harvest, lower yields and, therefore, a decrease in supply. Our production process is highly weather dependent, generally increasing in efficiency at moderate to high temperatures (but not extreme temperatures) and on sunny days.

The Price of Related Goods:
The price of related goods affects supply because as more units of commodities are demanded by individuals, the price will increase. Hence, the supply will be affected, consumers will purchase less, and producers will produce less. If urea fertilizer prices increase, our bio-fertilizer will become more competitive in the marketplace.

The Production Technology:
The manufacturing process involves selection of the most suitable strain of cyanobacteria for which market demand is identified, mass multiplication of the culture and packing, and production of the nutrient medium for the cyanobacteria. Our research in optimizing the production process is critical to making the technology both productive and robust in order to maximize the potential for success of the Village Level Product Promoters.

Task 3.3 Training Materials Drafted

We have drafted a manual entitled, "Building a Raceway for Cyanobacterial Bio-fertilizer Production." It is made up mostly of photographs with a small amount of text in order to improve its potential to be understood by people who speak a variety of languages and those who are illiterate. Later, another manual will be needed to describe the production

process and its management. In addition, the graduate students have drafted their theses, and we will use these as a basis for additional training materials. These materials will be very useful for the new students as a basis for further process optimization (depth and size of pond, color of lining materials) as well as for employees engaged in scaling up to villages throughout southern Ethiopia.

Task 4.1 List of Recommendations for Future Scale-up Drafted

Though there is need for additional research (for optimizing cyanobacterial bio-fertilizer production), at present we have quite sufficient results at hand which can be used for scaling up the technology. Thus, it is necessary to construct ponds near smallholders' villages for demonstration and dissemination purposes. We are currently planning to build ponds in the village of Chefe near Hawassa. We have drafted the list of recommendations below, and we will continue to refine these recommendations in the next quarter.

1. Work out step-by-step dissemination strategies. This could take various forms, via:
    a. Construction of ponds for interested model farmers so they will begin mass production. This approach creates an important platform for individuals in the community to share information and popularize the technology (neighborhood contacts and information exchange is a vital means of informal dissemination in villages).
    b. Along production scale-up activities, establish field plots (maize, kale) and fertilize with the cyanobacterial bio-fertilizer (as compared to controls) to demonstrate the effect of the fertilizer on growth and production of crops.
    c. Popularize the technology via farmers' field days (so that the pond as well as field plots will be visited by farmers).
    d. Provision of small amount of credits (especially for women) to construct their own cyanobacterial bio-fertilizer production ponds.
    e. Promote production for sale (especially the ground-dry cyanobacterial bio-fertilizer). However, its use has to be well established (popularized) and demanded in the community before the product is marketed.

2. Engage in further improvement and optimization activities/investigations (concurrently with activities mentioned above), including:
    a. Further exploration of new cyanobacterial strains and measurement of their growth and N fixing capacities. Until now, we have only studied three strains (E3, E5 and E9). These are different in their growth, biomass production and ease of harvesting. In view of the differences that we have observed and the thousands of strains lying resident in Ethiopian soils, there is a lot to do in this direction (isolation and screening).
    b. Research on pond size and depths, pond lining, frequency of aeration, temperature effects, etc.

3. Develop a self-propelling paddlewheel design (or design for a system which requires less energy, such as a pendulum). Availability of electricity is scarce in villages away from urban areas, and, therefore, this is of critical importance as we move forward.

Tasks for the Next Quarter

Task 1.4. Data Analysis

Task 2.4. Data Analysis

Task 3.3. Training Materials Tested and Revised

Task 4.2. List of Recommendations for Future Scale-Up Finalized

Thin Air Nitrogen Solutions
Grant No. AID-OAA-G-12-00015

Final Report to USAID- DIV **April 30, 2013**

Objective 1. Measure the yield impact of bio-fertilizer nitrogen as compared to urea

We had planned to initiate field studies in Chefe, a village near the city of Hawassa, in the previous quarter. However, due to inadequate production of bio-fertilizer for a field-scale experiment and an unexpectedly long rainy season in southern Ethiopia, we decided to test crop responses to cyanobacterial bio-fertilizer through greenhouse studies at this time.

Graduate students at Hawassa University carried out three greenhouse studies evaluating cyanobacterial bio-fertilizer impact on kale, maize, and chili pepper (Figure 1). These crops were chosen because of their importance in southern Ethiopia. Government-recommended fertilizer rates were used for each crop, and two soils (an acidic soil from Yirgalem and an alkaline soil from Ziway) were tested. Cyanobacterial bio-fertilizer was applied in either solid or liquid form, and in addition to a no-fertilizer control, urea was also applied at the same nitrogen rate for comparison purposes.

The urea, dry cyanobacterial bio-fertilizer, and liquid cyanobacterial bio-fertilizer consistently improved plant growth characteristics in kale, maize, and chili peppers as compared to the no-fertilizer control (Table 1). In both kale and maize, the dry cyanobacterial bio-fertilizer resulted in plant heights, leaf areas, shoot dry weights, root dry weights, and leaf N concentrations equal to the urea treatment applied at the same N rate. However, in chili pepper the dry cyanobacterial bio-fertilizer treatment consistently out-performed the urea treatment.

For most parameters measured in the kale and maize experiments, the liquid cyanobacterial bio-fertilizer did not perform as well as either the urea or dry cyanobacterial bio-fertilizer treatments. However, in the chili peppers, the liquid cyanobacterial bio-fertilizer achieved plant growth equal to those achieved with urea, but less than those measured in plants receiving dry cyanobacterial bio-fertilizer.

In addition, soil N contents at the end of the experiment were significantly higher in the dry cyanobacterial bio-fertilizer treatment in all three crops, apparently due to continued N fixation by cyanobacteria after application to the pots. This was also true for the liquid cyanobacterial bio-fertilizer in the kale and maize experiments. Overall, cyanobacterial bio-fertilizer applied to the soil in dry form was shown to more than double crop yields compared to the no-fertilizer control.

Figure 1. Graduate students with their greenhouse studies evaluating cyanobacterial bio-fertilizer in comparison with urea.

A) Girma Wolde and his maize experiment.

B) Mulatu Asmamaw with his kale experiment.

C) Mekiso Yohannes with his experiment on chili peppers.

Table 1. Plant characteristics and leaf and soil N contents of three crops grown on two soils under greenhouse conditions using different fertilizer treatments.

Fertilizer Treatment	Plant Height	Leaf Area	Shoot Dry Weight	Root Dry Weight	Leaf N	Soil N
	--cm--	--cm^2--	--------g--------		--------%--------	
			kale			
Control	29.2[c]	261.3[c]	1.98[c]	0.36[c]	4.16[c]	0.15[c]
Urea	38.5[a]	629.0[a]	4.29[a]	0.89[a]	6.14[a]	0.23[b]
Dry Cyanos	40.0[a]	647.7[a]	4.38[a]	1.01[a]	6.47[a]	0.27[a]
Liquid Cyanos	34.9[b]	387.5[b]	3.19[b]	0.64[b]	5.46[b]	0.26[a]
			maize			
Control	32.4[c]	269.4[c]	1.24[c]	0.92[b]	2.16[c]	0.20[c]
Urea	41.5[ab]	525.7[a]	2.59[a]	1.58[a]	4.14[a]	0.22[b]
Dry Cyanos	45.0[a]	539.5[a]	2.82[a]	1.49[a]	4.47[a]	0.24[a]
Liquid Cyanos	39.9[b]	407.7[b]	2.32[b]	1.61[a]	3.46[b]	0.24[a]
			chili pepper			
Control	13.3[c]	161.2[c]	5.14[c]	0.90[c]	2.39[c]	0.15[c]
Urea	18.0[b]	326.9[b]	8.31[b]	1.96[b]	4.33[b]	0.25[b]
Dry Cyanos	22.7[a]	404.6[a]	13.95[a]	2.96[a]	5.25[a]	0.33[a]
Liquid Cyanos	18.8[b]	332.5[b]	9.49[b]	2.17[b]	4.55[b]	0.27[b]

Means followed by a common letter within a column are not significantly different at $p \leq 0.05$.

Objective 2. Calculate costs, benefits, economic feasibility, and cost effectiveness of bio-fertilizer production in Ethiopia

Production Potential

Based on our 1 x 2 m prototype ponds, we have calculated the production potential from full-size prototypes. The 300-L ponds yielded 28.2 mg N/ L in a 3-week growth period during a cool, cloudy season. We expect to be able to produce cyanobacterial bio-fertilizer year-round in southern Ethiopia, and we predict that bio-fertilizer yields will be higher during warmer, dryer seasons. Nonetheless, we used these measured values to calculate production potential in order to be conservative in our calculations.

Based on an average need of 50 kg N for a hectare of vegetable production, we would need to set aside about 6.8% of a hectare in order to produce enough N fertilizer to grow a full hectare of vegetables. This is better than our original predictions of 10%; therefore, we are pleased with this level of productivity, and we expect to improve productivity further in the future as we optimize the production system.

Cost Effectiveness

When we began working in Ethiopia in 2010, the cost of 50 kg of urea fertilizer (46% N) was 350 birr or $25. That was already two to three times the cost of urea in the U.S.A. Due to widespread inflation in Ethiopia and reduced exchange rates with the US Dollar, today's price is 631 birr or $35 for 50 kg. Since only 46% of urea is actually N, in order to buy 50 kg N for a hectare of vegetables, an Ethiopian farmer would have to pay 1372 birr or $77 (not including transportation costs).

The primary challenge for cyanobacterial bio-fertilizer production to be able to produce N fertilizer more cheaply than urea, is the cost of construction of the production raceways. After construction, the cost for consumables and labor is minor. Originally, we built 12 small raceways using wooden frames and plastic liners for research optimization purposes (Figure 2). This construction approach is too expensive for larger-scale bio-fertilizer production by smallholder farmers. Therefore, we have subsequently built and priced two other raceway types (Figure 3). The plastic lining material is imported and very expensive, making up 80% of the material cost of this type of pond (Table 2). On the other hand, using cement and gravel requires higher labor costs, due to the need for skilled laborers for installation. Overall, the raceway with a cement and gravel liner costs $30 more than the one with a plastic liner. However, the cement raceway is sure to last longer than the plastic-lined raceway. We are continuing to work on reducing pond construction costs in order to achieve profitability for cyanobacterial bio-fertilizer.

Figure 2. Cyanobacterial bio-fertilizer production optimization facility at Hawassa University.

Figure 3. Alternative raceway construction approaches. A. Soil dugout to be lined with plastic sheeting. B. Soil dugout with a cement and gravel liner.

Table 2. Raceway construction costs (in Ethiopian birr, ETB).

Cost Breakdown	Soil Dugout with Plastic Liner	Soil Dugout with Cement and Gravel Liner
Materials	4350	3710
	(3500 plastic alone)	
Labor	1200	2400
Total (ETB)	5550	6110
Total (USD)	$298	$328

Yield Impacts

Based on the greenhouse studies described above, the average crop yield more than doubled in response to cyanobacterial bio-fertilizer. Based on the data in Table 3, if we assume that cyanobacterial bio-fertilizer would double yield, the additional income to the farmer would be 6,900 birr/ha ($385/ha), 11,900 birr/ha ($665/ha), and 22,100 birr/ha ($1,235/ha) for kale, maize, and pepper, respectively. At a cost of $77/ha for urea, there is clear profit potential here, especially if we can produce cyanobacterial bio-fertilizer for less than the cost of urea.

In addition, crops grown with cyanobacterial bio-fertilizer have been measured to have more than twice the beta-carotene concentration (a precursor to vitamin A) than those fertilized with urea at the same N application rate. This substantially increases the value of the crops in an area where vitamin A deficiency is common.

Table 3. Typical yields and prices for Ethiopian crops in Ethiopian birr (ETB).

Crop	Typical Yield	Current Retail Price in SNNP
	--kg/ha--	--ETB/kg--
Kale	1380	5
Maize	1700	7
Chili Pepper	1300	17

SNNP is the Southern Nations Nationalities and Peoples Region of southern Ethiopia.

Objective 3. Develop and test training materials, distribution channels, and branding strategies

Training Materials

We have drafted a training manual for Ethiopian bio-fertilizer producers (Figure 4). It is made up mostly of photographs with a small amount of text in order to improve its potential to be understood by people who speak a variety of languages and those who are illiterate. We plan to add text on the investment required, opportunities for credit, and Return on Investment and breakeven expectations to this manual as we develop that information.

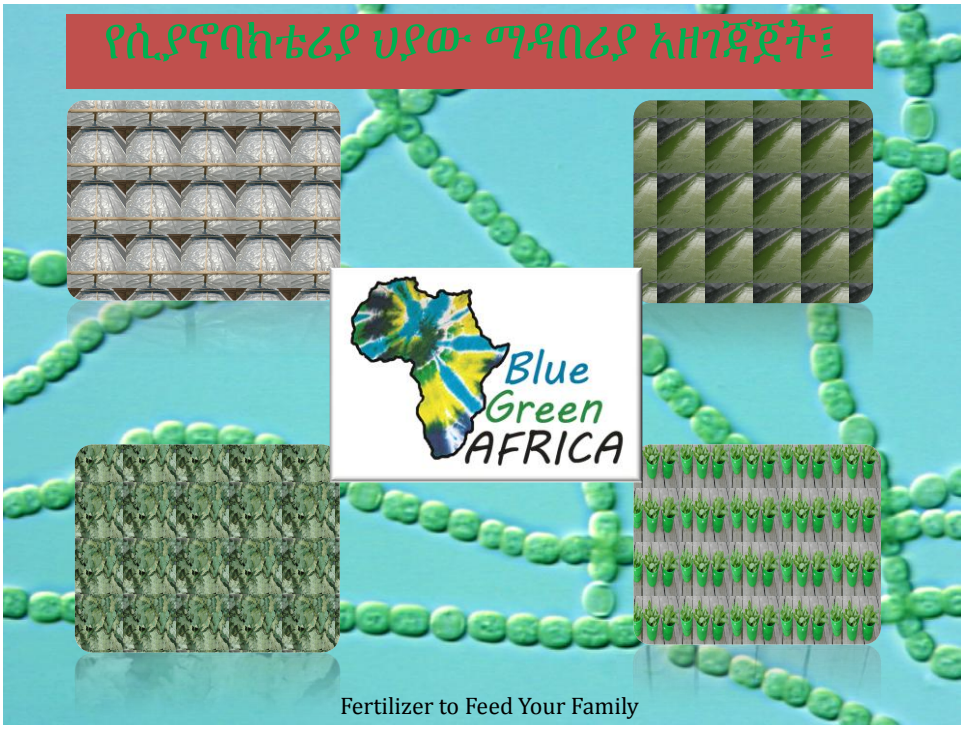
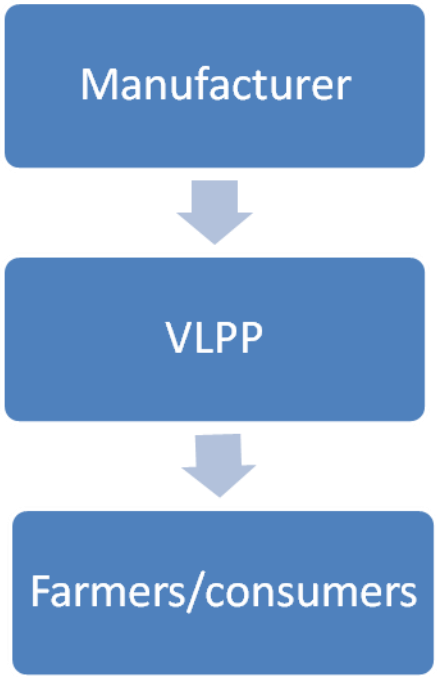


Figure 4. Cover of training manual for Ethiopian cyanobacterial bio-fertilizer producers.

Distribution Channels

Efficient distribution channels are critical to being able to deliver products and services to consumers quickly and cheaply. We are currently evaluating two different approaches for our business model and product distribution. Our original business model is based on empowering farmers to produce fertilizer on-farm through provision of goods (start-up kits, consumables) and services (training, troubleshooting). In this model, we will sell goods and services directly to the consumer rather than through retailers. However, we are

planning to use Village-Level Product Promoters (VLPP) who are early-adopter farmers, and who also serve as the front line sales and field staff. The VLPPs will demonstrate the fertilizer production system on their own farms for neighboring farmers to learn about and will also serve as technical experts for their neighbors. The VLPPs will make the distribution and sales processes more efficient and effective since they will play an important role in mobilizing smallholder farmers since they are trusted members of the farming community. In this model, Thin Air Nitrogen Solutions would utilize the marketing channel diagrammed below. Pickup trucks will be utilized for delivery of start-up kits, but motorcycles could be used for delivery of consumables and troubleshooting services.



Recently, we have begun to reconsider the original business model for several reasons. First, having farmers as fertilizer producers requires them to take a fair amount of risk on an unknown (and currently unproven) process. This is not a reasonable expectation for low-resource farmers. Secondly, there are issues regarding power (to turn the paddlewheel) and water availability that may restrict the locations where on-farm bio-fertilizer production is feasible. These concerns have led us to develop a new business model based on a distributed network of "Fertilizer Farms." These would be placed throughout the countryside on the outskirts of the market towns in order to maintain the benefits of reduced transportation and improved access for rural farmers. The Fertilizer Farms would sell cyanobacterial bio-fertilizer directly to farmers, with primary sales occurring on market days from a booth, but additional sales could be made directly from the Fertilizer Farms. A portion of each Fertilizer Farm would be set aside for demonstration purposes so that farmers can see the impact of the fertilizer for themselves. We do not expect that VLPPs would be necessary in this model.

Branding Strategies

Thin Air Nitrogen Solutions is a US-based company, and we plan to establish an Ethiopian-based subsidiary called Blue Green Africa. Blue Green Africa's image will be of professionalism and empowerment of Ethiopian entrepreneurs. We have designed a logo (Figure 5), and this logo will be utilized on our buildings, vehicles, and supplies. In addition, employees will wear blue-green tie-dyed shirts and baseball caps with the Blue Green Africa logo on them. The tagline will be "Fertilizer to Feed Your Family".

Figure 5. Logo for Blue Green Africa, a wholly-owned subsidiary of Thin Air Nitrogen Solutions, LLC based in Hawassa, Ethiopia.

In addition, when BGA Bio-fertilizer producers choose to sell the product to other farmers, they will participate in our Quality Assurance/Quality Control program, and when all standards for fertilizer quality are met, they will receive Blue Green Africa bags in which to store and sell the fertilizer. Bags will include the logo and tagline.

Blue Green Africa's advertising will follow a multi-pronged approach: field demonstrations, radio, video, and billboards. At the beginning (even prior to launch), and later when we expand into new territory, we will install field demonstrations at early-adopter farms. Early adopters will be given a discount in exchange for their willingness to host field days

for neighboring farmers to come and see the BGA Bio-fertilizer production process for themselves. Farmer-to-farmer communication will be the primary mode of communication at field days, because the level of trust and confidence is high between farmers.

We will run radio spots three times a week for the first month after launch and weekly thereafter. In addition, we will make a video explaining the fertilizer production process and interviewing early adopters, and then show this video in villages throughout southern Ethiopia using mobile battery-powered projection equipment.

We will also create billboards at the entrances to the major market towns to increase brand recognition and identification of Blue Green Africa as a company that empowers local entrepreneurs to feed their families. To network with customers, we will develop displays to show on regional market days. These displays will have minimal written language (tagline only) and focus on illustrations that present the basic idea of Blue Green Africa and the potential benefits to families.

Objective 4. Summarize research results into a list of recommendations for future scale-up of technology and dissemination through Ethiopian entrepreneurs

We have had sufficient success to date to begin scaling-up. We are currently planning to build ponds in 2013 in the village of Chefe near Hawassa for demonstration and dissemination purposes. Our recommendations for future scale-up are listed below.

1. Work out step-by-step dissemination strategies. This could take various forms, via:
   a. Construction of ponds for interested model/partner farmers so they will begin mass production. This approach creates an important platform for individuals in the community to share information and popularize the technology (neighborhood contacts and information exchange is a vital means of informal dissemination in villages).
   b. Development of a Fertilizer Farm and promotion of bio-fertilizer production for sale (especially the dried, solid cyanobacterial bio-fertilizer). However, its use has to be well established in order to build community-level demand before the product is marketed.
   c. Establishment of field plots (maize, kale) fertilized with the cyanobacterial bio-fertilizer to demonstrate the effect of the fertilizer on growth and production of crops.
   d. Popularization of the technology via farmers' field days (so that the ponds as well as field plots will be visited by farmers).
   e. Provision of credit (especially for women) for villagers to construct their own cyanobacterial bio-fertilizer production ponds and expansion of market analysis to women heads-of-household.
   f. Development of agricultural extension strategies to support resource poor farmers in achieving economic and nutritional benefits from the technology.

2. Engage concurrently in improvement and optimization activities including:
   a. Further exploration of new cyanobacterial strains and measurement of their growth and N fixing capacities. To date, we have only extensively studied three strains (E3, E5 and E9). These are different in their growth, biomass production and ease of harvesting. In view of the differences that we have observed and the thousands of strains residing in Ethiopian soils, the potential benefits of isolation and screening are substantial.
   b. Research regarding physical and material aspects of production, including pond size and depth, pond lining, frequency of aeration, and temperature effects.
   c. Development of criteria for water quality and quantity in order to site bio-fertilizer production ponds in areas with greater chance of success.
   d. Development of a nutrient solution using only locally-available ingredients.
   e. Development of a self-propelling paddlewheel design (or design for a system which requires less energy, such as a pendulum). Electricity is scarce in villages away from urban areas, and, therefore, this is of critical importance in order to maximize efficiency and minimize cost.