

ONE ACRE FUND

Maize-Legume Intercropping
2014 Phase 1 and 2 Trial Report



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Background

Maize was originally domesticated in Mesoamerica approximately 10,000 years ago. The native Mesoamericans developed an ingenious maize intercropping system with beans (known as “the three sisters,” along with squash) that sustained agricultural productivity for millennia. In this intercropping system the particular biology of the two crops are exploited and synergized. Maize is a heavy feeder of soil nitrogen. Beans are legumes, meaning they are able to increase soil nitrogen by biologically extracting nitrogen from the air, termed nitrogen fixation. Smallholder farmers in Africa also commonly use maize/bean intercropping to increase soil nitrogen and agricultural productivity. One Acre Fund conducted a series of maize/legume intercropping trials in order to determine the optimum species and arrangement to provide farmers with significant and positive economic and food security impacts.

Results Summary

- **Primary product configuration tested:** One Acre Fund trialed eleven different maize and legume intercropping combinations in the research station and in on-farm trials in two different trial districts in Kenya.
- **Land Equivalency Ratio (LER):** The land equivalence ratio (LER) is a measure of the land area of monocrop maize or legumes required to equal that of the intercrop. An LER less than 1 indicates that more land is needed in the intercrop to equal the productivity of the monocrop. An LER greater than 1 indicates that less land is needed in the intercrop to equal productivity of the monocrop. Measured LERs from the One Acre Fund trials ranged between 0.7 – 5.7.
- **Potential value of intervention:** Current One Acre Fund farmers have strong preferences for planting legumes as intercrops with maize over legume monocrops. In addition to productivity gains, additive benefits accrue when legumes are intercropped. In the long-rain season of 2014 there were several strong hail events. The monocrop legumes grown on the research station were decimated. However, the legumes grown in the intercrop were protected from the hail damage.
- **2015 trials:** Farmer preference was strongest with the simple maize and bean intercrop, alternating 1 row of maize followed by one row of beans. We will be moving the simple maize and bean intercrop to phase 3 (1000+ farmers) in 2015.

I. Product Rationale and Approach

- **Purpose:** Legumes are an integral part of smallholder agroecology. They provide a highly nutritious source of high-protein food, have higher market value than maize, and are capable of biological nitrogen fixation to increase the on-farm nitrogen economy.
- **Rationale:** The monocropping of beans in East Africa is relatively low; farmers have high preference for intercropping of beans with staple grains (e.g. maize). However, the common practice is to place the maize and bean seeds together in the same hole. This practice is known to decrease nutrient use efficiency as it encourages inter-crop competition. In addition, there are many different species of legumes that are commonly intercropped, for example common beans (*Phaseolus vulgaris*), soybean (*Glycine max*), and groundnuts (*Arachis hypogaea*). Each

separate legume species as a unique root and leaf architecture and will require different planting spacing to maximize the synergies between the grain and legume crop.

- **Our approach:** A best management practices trial was conducted during the long-rain season of 2014 in western Kenya. The best management practices for the intercropping included common bean, soybean, and groundnut all intercropped with maize. The trial configurations included simple intercropping (alternating single rows of maize and legume) and the “mbili” system of intercropping (alternating two rows of maize and then two rows of the legume). The trials were conducted in both the research station (phase 1) and in on-farm trials (phase 2).
- **Trial selection criteria:** These trials were selected based on the four criteria of impact (incremental dollar income added to the farmer), adoption (farmer demand), complexity (ability to realize return) and operability (scale potential).

II. Partners Consulted

One Acre Fund consulted with several public and private research centers and organizations (many of them funded by the Bill and Melinda Gates Foundation) with decades of legume intercropping experience. The knowledge partners included:

- **KALRO** – Basic agronomy, variety recommendations, genetic material supply
- **N₂Africa** – Developed “mbili” system, best management practices recommendations
- **Mea Fertilizer** – Provided fertilizers and legume inoculants
- **CIAT** – Assisted with variety recommendations

These organizations were extremely helpful and were excited to see their research being put into farmers’ hands.

III. Phase Configurations (Phases 1-2)

One Acre Fund tested improved intercropping practices, summarized below.

Farmers First

Table 1. Configurations of the improved intercropping practices trials, Kakamega research station (phase 1) and Bungoma South (phase 2) trial district in the long-rain season of Kenya, 2014.

Trial treatment	Trial control	Management	Trial phase/ # farmers
Common bean mbili – no fertilizer	<ul style="list-style-type: none"> Maize monocrop – WEMA 1101 Beans monocrop – KK8 	<ul style="list-style-type: none"> Treatment – no fertilizer Control - 123.5 kg DAP/ha at planting; 123.5 kg CAN at topdress 	<ul style="list-style-type: none"> 1 – Kakamega station Farmers – N/A
Common bean mbili	<ul style="list-style-type: none"> Maize monocrop – WEMA 1101 Beans monocrop – KK8 	<ul style="list-style-type: none"> 123.5 kg DAP/ha at planting 123.5 kg CAN at topdress 	<ul style="list-style-type: none"> 2 – Bungoma south Farmers - 281
Common bean mbili	<ul style="list-style-type: none"> Maize monocrop – WEMA 1101 Beans monocrop – KK8 	<ul style="list-style-type: none"> 123.5 kg DAP/ha at planting 123.5 kg CAN at topdress 	<ul style="list-style-type: none"> 2 – Green Shamba Farmers - 150
Common bean simple – no fertilizer	<ul style="list-style-type: none"> Maize monocrop – WEMA 1101 Beans monocrop – KK8 	<ul style="list-style-type: none"> Treatment – no fertilizer Control - 123.5 kg DAP/ha at planting; 123.5 kg CAN at topdress 	<ul style="list-style-type: none"> 1 – Kakamega station
Common bean simple	<ul style="list-style-type: none"> Maize monocrop – WEMA 1101 Beans monocrop – KK8 	<ul style="list-style-type: none"> 123.5 kg DAP/ha at planting 123.5 kg CAN at topdress 	<ul style="list-style-type: none"> 1 – Kakamega station
Common bean simple	<ul style="list-style-type: none"> Maize monocrop – WEMA 1101 Beans monocrop – KK8 	<ul style="list-style-type: none"> 123.5 kg DAP/ha at planting 123.5 kg CAN at topdress 	<ul style="list-style-type: none"> 2 – Bungoma south Farmers 173
Soybean mbili	<ul style="list-style-type: none"> Maize monocrop – WEMA 1101 Soybean monocrop – Squire 	<ul style="list-style-type: none"> 123.5 kg DAP/ha at planting 123.5 kg CAN at topdress Biofix to soybeans 	<ul style="list-style-type: none"> 1 – Kakamega station
Soybean simple	<ul style="list-style-type: none"> Maize monocrop – WEMA 1101 Soybean monocrop – Squire 	<ul style="list-style-type: none"> 123.5 kg DAP/ha at planting 123.5 kg CAN at topdress Biofix to soybeans 	<ul style="list-style-type: none"> 1 – Kakamega station
Groundnut mbili	<ul style="list-style-type: none"> Maize monocrop – WEMA 1101 Groundnut monocrop – Homa Bay Local 	<ul style="list-style-type: none"> 123.5 kg DAP/ha at planting 123.5 kg CAN at topdress Apronstar seed coat 	<ul style="list-style-type: none"> 1 – Kakamega station

A. Phase 0: Research

The first stage of OAF product development cycle is a research phase that compares potential intervention configurations to our four product selection and evaluation criteria:

Criteria	Evaluation Question
Impact	<i>Can the product significantly increase client income?</i>
Adoptability	<i>Are a significant number of clients willing to purchase this product?</i>
Simplicity	<i>Is the product simple enough that all clients can achieve a consistent result?</i>
Operability	<i>Can we scale this product with a minimal increase in operational complexity?</i>

Preliminary surveying and exploration of the benefits of legume intercropping were investigated through desk research and through conversations with global experts. A brief synopsis of the initial research is summarized below.

Table 2. Primary considerations for evaluating the benefits of legume species and legume/maize intercropping configurations.

Selection Criteria	Common bean	Soybean	Groundnuts
Yield	- Average yields in SSA 530 kg/ha - Yield potential exceeding 2000 kg/ha	- Average yields in SSA 830 kg/ha - Yield potential of 5000 kg/ha	- Average yields in SSA 950 kg/ha - Yield potential of 2500 kg/ha
Nitrogen fixation capacity	- Bush bean: 35 kg N/ha - Climbing bean: up to 125 kg N/ha	- Greater than 200 kg N/ha	- 150 kg N/ha
Simplicity	- <i>Simple intercrop</i> : Requires slight management and protocol changes to core maize and bean program - <i>Mbili intercrop</i> : Requires substantial changes in management and protocol in maize and bean core program	- <i>Simple intercrop</i> : Requires slight management and protocol changes to core maize and bean program - <i>Mbili intercrop</i> : Requires substantial changes in management and protocol in maize and bean core program	- Groundnuts require more space to mature than other grain legumes due to seed maturation occurring underground. The mbili system is the only trialed intercropping method that provides adequate space.
Operability	- To be feasible at scale we will need to develop and train farmers on best management practices for maize and bean intercropping for both yield potential and N fixation potential	- Soybean is a relatively new crop for many of the One Acre Fund farmers. Best management practices and farmer awareness for soybean need to be developed	- Of all of the trialed legumes, groundnut is the most operationally complex. Groundnut seeds have a limited shelf-life and are more fragile than other legume seeds

Common bean, soybean, and groundnut were chosen, as they are the most commonly planted intercropped legumes among One Acre Fund farmers. Much of the intercropping methodology came from N₂Africa. N₂Africa have done extensive field testing of these methodologies and common bean, soybean, and groundnut are three of their four core crops.

In Phase 0, we estimated a farmer economic model as shown below. It should be carefully noted, however, that the below economic model is based on urea – nitrogen (N) fertilizer value from 2014. The costs of urea are variable by year and season.

Farmers First

Table 3. Initial economic analysis of the fertilizer value from legume species in maize/legume intercropping trials.

Nitrogen fixation (% potential value)	Biological N fixed available in next season		
	Common bean	Soybean	Groundnut
60%			50%
<i>N-fixation value</i>			
N available to second season crop (kg/ha)	10.5	60	45
Total fertilizer savings (USD/ha)¹	\$187	\$1,068	\$801

1. Fertilizer N value is based on the unit price of urea in 2014, USD \$409 per 50kg.

Although directly quantifying the monetary value of fertilize N savings from biological N-fixation is difficult, in other field trials One acre Fund has successfully reduced fertilizer use with common beans by half and maintained yields relative to our fully fertilized control. Having an empirical evaluation of fertilizer savings from different legumes, albeit with caveats, will allow us to better design trials that test these assumptions.

B. Phase 1: Research Station Configurations

Research station trials focused on identifying the highest yielding intercropping management system both within legume species and between legume species. A variety of factors were considered:

Seed variety selection

Common bean – KK8 was selected as the standard variety for common bean. This variety was used on all intercropping trials with common bean. KK8 is an improved variety of rose coco (a widely grown bush bean) with higher resistance root rot diseases.

Soybean – The soybean variety Squire was used it has good resistance to soybean rust disease. In addition, in soybean a rhizobial inoculant was used as soybean requires a specific rhizobial species (*Bradyrhizobium japonicum*) that is not common in African soils.

Groundnut – The groundnut variety Homa Bay Local was used as it is the most commonly planted improved groundnut variety in western Kenya.



Early season maize soybean simple intercropping plot in the Kenya research station. Kevan Christensen/One Acre Fund.

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Intercropping system

The most common local intercropping practice is to plant the legume (usually common beans) in the same planting hole as maize. While common, this practice leads to interspecies competition for water and nutrients. Improved intercropping practices include placement of the legume species in between rather than within the rows of maize. However, in this system the legume yields are often compromised as they are shaded by the maize plants. N₂Africa have developed the mbili system (mbili means two in Swahili) where two rows of maize are followed by two rows of the legume species. The increased spacing theoretically reduces the amount of shading on the legume rows.



*Mbili maize soybean intercrop system in a farmer's field.
Kevan Christensen/One Acre Fund.*

Hypothesis: Utilizing the mbili system for legume/maize intercropping will increase productivity (yields and LER) as the legume crops are not as strongly shaded by the maize relative to the simple intercropping system.

Two intercropping systems were tested:

- 1) The simple intercropping system: alternating single rows of maize and the legume (see figure 2).
- 2) The mbili system: alternating double rows of maize and the legume (see figure 3).

C. Phase 2: On-farm Trial Configurations

Treatment selection

Three legume-maize intercropping configurations were chosen to be trialed in phase 2. Two trial districts were used that represent contrasting agroecological zones. The trial districts were Bungoma South, classified as a mid-altitude high-rainfall agroecological zone; and Gucha-Rachuonyo, classified as a mid-altitude low-rainfall agroecological zone.

- 1) Simple systems with common bean (Bungoma South) – 173 farmers.
- 2) Mbili system with common bean (Bungoma South and Gucha-Rachuonyo) – 281 and 150 farmers, respectively.
- 3) Mbili system with soybean (Bungoma South) – 170 farmers.

Hypothesis: Greater productivity from the mbili intercropping system will result in greater farmer preference and adoption of the mbili system relative to the simple legume/maize intercropping planting method.

IV. Trial Results

A. Phase 1 trial results:

LER: The Land Equivalent Ratio (LER) is the most common metric for determining the efficiency of intercropping systems. In most cases, the component yields of each of the plant species in the intercropping system are lower than the equivalent monocrop yields. This is due to the previously mentioned shading effect. The LER is calculation with the following formula:

$$LER = \sum_{i=1}^M \frac{y_i}{y_{ii}}$$

where,

- y_i is the yield of the “ i ”th component (e.g. maize only or legume only) from a unit area of the intercrop;
- y_{ii} is the yield of the same component grown as a sole crop over the same area.

Using this analysis we are able to determine the relative land area of the monocrop required to equal the combined productivity of the intercrop. A LER equal to one means there is not comparative advantage to either the monocrop or the intercrop; a LER > 1 is interpreted as the monocrop will require more land (the value above 1) to equal the same total productivity as the intercrop; for a LER < 1 the opposite is true.

Table 4. LER for the various intercropping trials at the Kakamega research station, long-rain season of 2014. Different letters indicate significant differences between treatments, if all letters are the same there are no significant differences (Tukey’s HSD P = 0.05, n = 6)

Trial	LER
Common bean simple – no fertilizer	1.3a
Common bean simple – fertilizer	1.0a
Common bean mbili – no fertilizer	1.7a
Common bean mbili – fertilizer	1.6a
Soybean simple – fertilizer	1.22a
Soybean mbili – fertilizer	1.36a
Groundnuts mbili - fertilizer	1.3a

Impact

We found LERs greater than 1 for all of our trials except for the common bean with fertilizer. In this treatment the LER was 1. These data indicate that intercropping legumes with maize can result in positive benefits to land productivity and crop and market diversity for One Acre Fund farmers. The positive N economy of intercropping legumes with maize also lends supporting evidence to the benefits of intercropping systems.

B. Phase 2 trial results:

Table 5. LER and farmer preference for the various intercropping trials in Bungoma South and Gucha-Rachuonyo trial districts, long-rain season of 2014. Farmer preference is the percent of trial farmers in each district who indicated that they would be willing to purchase the offering in the following season.

Trial	Monocrop yield – maize (t/ha)	Intercrop yield – maize (t/ha)	Intercrop yield – legume (t/ha)	Total combined yield (t/ha)	Total yield relative to the monocrop control (%)	Farmer preference (%)
Common bean simple	5.4	5.3	0.4	5.7	+5%	65
Common bean mbili – Bungoma South	3.4	1.9	0.3	2.3	-33%	49
Common bean mbili – Green Shamba	0.8	0.7	0.3	1.0	+25%	71
Soybean mbili	5.6	5.7	3.1	8.8	+57%	43

Impact

With the common bean, the simple intercrop resulted in the greatest total yield. The yield of the intercrop maize was not different from the monocrop, however, total yield (the combination of maize and beans) benefited from the addition of the beans. The mbili system with common bean resulted in poor yields in the Bungoma south trial district, both in the monocrop maize and in the total intercrop yield. However, when grown in the Green Shamba trial district (hotter and drier than Bungoma South), the total intercrop yield was 25 percent greater than the maize monocrop. Soybean performed very well when grown in the mbili system. Resulting total yields were 57 percent greater than the maize monocrop.

Operability

Sourcing: Maize and beans are the two most common crops in East Africa and the seed industry is well developed and robust. There are no operational difficulties in sourcing these seeds.

Distribution: There are no obstacles to the distribution of maize and bean seeds. These two crops are the foundation of the One Acre Fund program.

Training complexity: There are substantial complexities in training farmers on multiple intercropping methodologies. The simple intercropping system is the easiest methodology as it requires only subtle changes to the existing program. The mbili system is more complex, at scale the additional complexity will require substantial efforts to train field staff and to ensure that the planting methods are followed.

Next steps for 2015

- 1) The simple bean intercropping package will be moved up to an entire trial district in 2015 (1000+ farmers).

- 2) We will be trialing a simple soybean intercrop in phase 2 (100+ farmers).

VI. Conclusion and next steps

In East Africa legumes are commonly grown in and intercrop with maize. Our preliminary work has demonstrated that there is variability in the yield impact of different intercropping systems and with different legume species. We have identified the simple intercropping system as one that provides a measureable yield benefit in addition to being easy to implement.

A. Yield and profit

- Total combined yield (maize and the legume) ranged from 1 t/ha with an mbili maize and common bean system in drier areas to 8.8 t/ha with a mbili maize/soybean system in the humid highlands. Similarly, LERs ranged from 1 with a simple maize and bean system to 1.7 with a maize and common bean mbili system.

B. Farmer adoption

- For the 2015 season in Kenya, the adoption rates were 8% for maize and common bean simple intercrop and 0.5% for maize and soybean. However, when farmers reviewed the intercropping on-farm trials, farmer preference for the intercropping over the monocrop ranged from 43 – 71%. This is a clear indication that farmer perception of the value of improved intercropping can be high with sufficient exposure.

C. Operability at scale

- There are no perceived obstacles to procuring the intercropping seeds, both maize and the legume. The seed sector for both of these crops is established and robust.
- Training farmers and field officers in the intercropping methodology might be challenging, particularly with the more complex mbili system. However, if sufficiently justified these barriers can be overcome.

D. Next steps

- In phase 1 (research station) all new legume varieties or management tools (fertilizers and pesticides) will be trialed as an intercrop with maize or other grains (e.g. pigeon peas and sorghum).
- The common bean and soybean intercrop were both offered at scale within one trial district in 2015. However, adoption rates of both of these were very low. In 2015 we will be trialing methods for improving adoption rates of new products.
- We will be trialing a simple soybean intercrop and a green gram and maize intercrop at phase 2 (100+ farmers).